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VOL. II. THE GEOLOGY OF CROWLEY'S RIDGE.
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TABLE OF CONTENTS.

PAGE.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

ST. FRANCIS COUNTY.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXV.

CHAPTER XXVI.

PREFACE.

This volume of the Geological Survey's reports relates principally to Crowley's Ridge—the only marked topographic prominence in the country between Little Rock and Memphis. From near Cape Girardeau in Missouri to Helena, Arkansas, Crowley's Ridge is broken in but few places, and rises usually over a hundred feet above the level of the country on either side of it.

The striking contrast between the ridge and the broad belt of flat country on either side of it has not failed to impress the people living in the region as well as geologists; how, and when, and the conditions under which it was formed are therefore matters of general as well as of special interest.

The map of the ridge.—The history of Crowley's Ridge, is intimately interwoven with that of all Eastern Arkansas and of the immediate valley of the Mississippi River. This has made it necessary to study and to have a map of the whole area traversed by the ridge. Such a map accompanies the report and will be found in the pocket in the cover of this volume. No attempt is made to color this map geologically for the data at hand will not permit it. In general, however, the Tertiary forms a narrow band of varying width outcropping (when not concealed by talus) along both sides of the ridge throughout its entire length, while in places it rises to the very crest of the ridge.

The Tertiary outcrop occurs again on the margin of the highlands southwest of Newport between Grand Glaise and Bradford, White county. If the gravels on the highlands are the equivalents of the Orange Sands of Crowley's Ridge, and granting the Tertiary age of the latter, then the Tertiary caps the

hills that skirt the western side of the immediate Black River valley. On the eastern side of the flooded area the Tertiary crops out along the base of the Mississippi River bluffs in Tennessee from the Mississippi state line to Reelfoot Lake, and in Kentucky the same beds extends from Hickman to near Cairo.

The origin of Crowley's Ridge.—Inasmuch as Professor Call devoted himself to the study of the Arkansas part of Crowley's Ridge only, the following brief sketch of the history of the ridge and of its relations to the country about it is given here for the purpose of embracing features that are necessarily omitted from his part of the report.

In Tertiary times, the predecessor of the Gulf of Mexico extended much further north than the Gulf now does. That body of water covered a large part of Texas, all of Louisiana, most of Mississippi, much of western Tennessee, and all of eastern and southern Arkansas. The western shore of this sea in Arkansas, entered the state near Ultima Thule in Sevier county, followed the foothills through Howard, Pike and Clark counties, passed near the old town of Rockport in Hot Spring county, and thence kept west of the Iron Mountain Railway to Little Rock. All the ground upon which Little Rock now stands was covered by the waters of that sea, while to the north the shore line followed west of the Iron Mountain Railway, and at the northwest corner of Clay county passed into what is now the state of Missouri. From this point it bent eastward to the vicinity of Cairo, Illinois, passed into Kentucky and curved southward past Paris, Huntington and Middleton, in West Tennessee.

Into the great sea thus briefly outlined the waters of the Mississippi, of the Arkansas, and of hundreds of other streams poured vast quantities of mud which were deposited over the bottom of this body of water just as similar materials are being deposited to-day in the Gulf of Mexico. We know this to be true, not by analogy alone, but because we find here and there over this old sea bottom the remains of the ancient deposits of clays and sands containing the fossil remains of the marine animals that lived during Tertiary times. The total depth of

the deposits originally made in this Arkansas sea we do not know, because the upper parts of the beds have been washed away, but the remaining fragments throw much light on the subject.

At Little Rock, for example, what is known as Capitol Hill is the highest part of the city, and this hill is capped with Tertiary beds* that rise to an elevation of 380 feet above present tide level. But this Tertiary deposit is only a fragment of what it originally was, for the beds are cut off abruptly to the east and south showing that they formerly extended further in those directions. But to the east and south the land is now much lower, the general elevation being about 225 feet above tide, suggesting that a thickness of something like 150 feet has been removed from what is now the lower country to the east.

At and near Grand Glaise, Jackson county, the conditions are very similar to those just mentioned. The Iron Mountain Railway between Bradford and Grand Glaisé follows the foot of the Tertiary escarpment of horizontally bedded rocks which end abruptly on the east, while to the west they abut unconformably against paleozoic rocks. This Tertiary margin rises 100 feet or more above the flat country to the east.

These beds are, of course, the fragmentary remains of those which once extended away to the east and connected with others of the same age in what is now Crowley's Ridge and with still others in the Tertiary highlands of West Tennessee.

In Crowley's Ridge itself we have the Tertiary capping the ridge at many, though not all places, and rising to an elevation about 350 feet above present tide level, 120 feet above the lower lands to the east and west. Now, bearing in mind that these Tertiary beds were all laid down in the same sea bottom, and that the parts now visible are but fragmentary, it follows that the extension of these beds between Little Rock and Grand Glaise on the west and Crowley's Ridge on the east once carried them across the entire valley from which they have been removed. The same line of argument applies to the valley region

* The Tertiary does not form the immediate surface of Capitol Hill, but is covered by a bed of waterworn material, cobbles and pebbles. The blue clays and impure limestones found in the wells, however, are Teritary.

lying between Crowley's Ridge and the high Tertiary lands of West Tennessee from which similar beds have been eroded. In general terms, then, it may be said that Crowley's Ridge is the result of the erosion along both sides of it.

The Mississippi River, instead of having always cut through the solid rock as it now does southeast of Cape Girardeau, formerly flowed west of Crowley's Ridge having a southwest direction at Cape Girardeau and flowing through the lowlands shown on the accompanying map. It flowed past Delta, Poplar Bluff, and Neelyville, and joined the Ohio somewhere south of Helena; subsequently it cut through Crowley's Ridge at Chalk Bluff and flowed down the St. Francis valley, and still later it cut the ridge between Bloomfield and Benton, Missouri, and joined the Ohio south of New Madrid. It and its predecessors were then the principal agents in the removal of the Tertiary beds that once filled the flat country between the ridge and the highlands west of it. While the Mississippi flowed through this Arkansas Valley, to the east of the ridge the Ohio was washing down similar beds on its opposite side, and it was not until towards the close of the glacial epoch that the old channel southwest of Cape Girardeau was filled up and the Mississippi cut through the hills to the southeast and joined the Ohio at Cairo.

It should be noted, however, that the materials forming the surface of the valleys both east and west of Crowley's Ridge are not Tertiary, but of later date; in other words, while these valleys were cut in Tertiary strata, they were cut much deeper than we now find them and were afterwards partly refilled by the loose sands, gravels, clays and loams that now form the surface of the country. The well sunk in the bottoms at Helena was in this old refilled channel, while those at Lonoke, Augusta, Cotton Plant, England, Morton, and at all other points in the valley at which data have been collected are in material brought down by the Mississippi during the second glacial epoch and spread out in these old channels. It was during the latter part of this period that the long silt ridges like that extending along the east side of Black River from near Newport past Walnut Ridge were formed.

From this brief sketch it will be seen that Crowley's Ridge has been produced by the simple processes of building up and tearing down sediments, and that it is in no respect an upheaval as is often suggested. But while the agencies that have made it are simple and familiar to every one, as Professor Call remarks on page 131, it "stands now a silent witness to a history so wonderful that the imagination is taxed by any attempt to compass all its details."

The chapter by Professor Salisbury.—Professor R. D. Salisbury, of Beloit College, Wisconsin, having given especial attention to the study of the phenomena connected with the margin of the drift and having studied the Crowley's Ridge deposits, was asked to write a chapter upon the relations of the northern drift to the Pleistocene deposits of that region. He kindly consented and his valuable paper is given as Chapter XXV., pp. 224 to 248, of this volume, where he clearly sets forth the suc-succession of events in the northern part of the United States during Pleistocene times, and points out the relations of those events to the influences that shaped Crowley's Ridge and its adjacent territory.

Since the chapter by Professor Salisbury was printed I have received from him the following letter which explains itself:

BELOIT, WIS., February 24, 1891.

My dear Dr. Branner:—In the chapter I sent you I should like to modify a point regarding the subdivission of the loess. I made a flying trip to the region in the Christmas vacation, and am thoroughly convinced that there is a two-fold division of the loess on Crowley's Ridge, and that the earlier subdivision corresponds to the first glacial episode of the first glacial epoch.

In the Forest City section there is an old soil separating two loesses. The old soil is not everywhere equally well marked. In places it is indistinct, but in other places it is unmistakable, and those parts which are less distinct are traceable into direct continuity with those which are sharply defined, making the identification of the whole pretty certain. At

numerous other points on Crowley's Ridge in Arkansas and Missouri, as also on the east side of the Mississippi valley, the indications of a subdivision of the loess are quite as well marked as in many parts of the Forest City section where there can be no doubt as to the fact.

Laboratory tests sustain the conclusion drawn from field observations, that organic matter is the coloring matter of the belt regarded as an old soil. That the loam above and below it is loess, is shown by its mineralogical constitution, its fossils, and its concretions.

The lower division of the loess is regarded as the fluvial representative of the first episode of the first glacial epoch, while the upper division of the loess is the corresponding representative of the second episode of the first glacial epoch, and the soil between the two loesses represents the interval between the two episodes.

You will readily see that this does not weaken any argument I have used, though it may seem to make some of them unnecessary, and does not in any way alter the conclusion arrived at. We have now, as I see it, the first glacial epoch fully provided for in the south by deposits overlying unconformably the Orange Sands.

Yours truly,

R. D. SALISBURY.

The work of Professor Knowlton.—Some of the fossil woods collected in eastern Arkansas were submitted to Professor F. H. Knowlton, of the U. S. Geological Survey, who has made a special study of the microscopic structure of such woods. Professor Knowlton's valuable paper, with illustrations, is appended to this report as Chapter XXVI., pp. 249 to 267.

Analyses.—The chemical analyses given in this volume, when not otherwise specified, have been made in the laboratory of the Survey by, or under the supervision of the Chemist, Dr. R. N. Brackett.

The St. Francis county report and map.—Special attention was given St. Francis county for the purpose of getting the key to the geology of the remainder of the ridge. Much of the re-

port (pp. 143 to 183) is therefore devoted to the geology of St. Francis county. The map of St. Francis county is from original work done by the Survey, and it will be useful as showing the contour and elevation of the ridge at one point which may be regarded as typical for much, though not for all of the ridge.

Economic minerals.—The clays—both fire-clays and brick clays—of this region hold forth promise of being very valuable if they are developed. The loess clays, abundant all along the southern half of the ridge, are the same as those used at St. Louis, Memphis, and in other parts of the country in the manufacture of the best grades of pressed bricks, as well as for the common grades. Some of the fire-clays commonly associated with the lignites are of excellent quality and may also be made valuable.

Other minerals of economic importance are not to be looked for in the rocks of eastern Arkansas; the iron ore occasionally found there is of no value, being limited in quantity and of very poor quality; the lignites are not valuable now and are not likely ever to become so, while other minerals of value are not to be looked for at all. This statement is made not only on account of the failure of the Survey to find such minerals there, but principally because the method by which the strata of that portion of the state were deposited, and their subsequent history preclude the possibility of any such deposits having been made in that portion of the state. The lumps of lead occasionally found in the region have been washed down from the lead-bearing rocks in the north along with the coarser gravels with which they are always associated.

Artesian water.—It will doubtless be expected that the Survey shall have something to say in this report of the possibility of obtaining artesian water in the eastern part of the state. The data that the Survey has been able to collect bearing upon this question is meagre and lacking in precise details, but it is sufficient to be of value.

The general principles of flowing wells are well understood, and it is only necessary to bear in mind that there must be:

1st. A water-bearing stratum or bed, usually of gravel or sand;

2nd. A confining impervious bed, usually of clay, overlying the water-bearing bed;

3d. A head, or source of supply higher than the mouth of the well, sufficient to bring the water to the surface when tapped.

The section of the Memphis wells given on p. 28, shows the existence at that place of the water-bearing sand bed at a depth of 1,215 feet, and of an overlying impervious bed. But these beds rise toward the east and come to the surface in the highlands of West Tennessee. This higher source of supply furnishes the head necessary to bring the water to the surface at Memphis where the wells penetrate the impervious beds and enter the water-bearing sands.

The question then arises whether water may not be had in the same way at Helena, at Forrest City, and at other points along Crowley's Ridge. But it should be remembered that a great trench, whose depth we do not know, has been cut in these Tertiary beds between Crowley's Ridge and Memphis and afterwards filled up, and it is quite possible that the confining strata overlying the water-bearing sands were cut through by this old erosion, and the possibility of a flow of water west of the channe thus destroyed.

If the source of supply is looked for to the west we find, *first*, that in the absence of deep well records we have no means of knowing the succession of the beds to any considerable depth, and, *second*, that, excepting the fragments left by erosion, and which have nothing to do with the question of water supply, the Tertiary strata are no higher at their western margin than in Crowley's Ridge, and consequently that there is no head to bring the water to the surface. No doubt a large water supply may be had from wells all through the eastern part of the state, but while the water will usually rise nearly to the surface, it will always require pumping.

Acknowledgments.—The people of all portions of the region studied have taken a deep interest in the work of the Survey, and their constant courtesy to the assistants has greatly facili-

tated it. Especial mention should be made of Hon. J. E. Riddick and of Mr. Richard Jackson, of Gainesville, who gave their time and personal guidance to important localities, and to Hon. Wm. E. Manning, of Goodwin, whose aid and interest in the work have enabled the Survey to make it more valuable.

JOHN C. BRANNER,
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THE GEOLOGY OF CROWLEY'S RIDGE.

By R. ELLSWORTH CALL, Assistant Geologist.

CHAPTER I.

INTRODUCTION.

The eastern half of the state of Arkansas is included within an area which, in comparatively recent geological time, was entirely submerged under a northward extension of the Gulf of Mexico. Reaching away southwestward from near the mouth of the Ohio river, in a nearly direct line, this old gulf had its western shore along the paleozoic escarpment which is approximately indicated in the state of Arkansas by the line of the St. Louis, Iron Mountain and Southern railway. The old shore line is just west of this road and rarely more than five miles and never more than twelve miles away. From near Newport southwards to Little Rock and to the Ouachita River near Malvern the strata composing the oldest Tertiary series of rocks, to which series the Tertiary strata throughout this area belong, lie unconformably upon paleozoic shales and sandstones. Southwestward from Rockport on the Ouachita to near Arkadelphia and onward to the state line near Texarkana the strata lie conformably, or nearly so, upon rocks of Cretaceous age, though the conformability is often broken. At some points, as at the great bluff of the Ouachita at Arkadelphia, the change in the macroscopic and lithologic characters of the rocks is so gradual that the line of demarkation between the Tertiary and Cretaceous strata cannot

be drawn with any degree of certainty. It is probable that at this point, if anywhere in the state, there may be seen absolute conformity both in stratigraphic and chronologic sequence between these members of the geologic column. At the base of this bluff are to be noted heavy beds of Cretaceous clays with characteristic fossils and these pass into Tertiary nonfossiliferous clays, probably of Eocene age, by gradations so insensible that no line of demarkation can be fixed upon between the two. The whole is surmounted with Tertiary Orange Sands and gravels and with Pleistocene clays, making complete though puzzling sections.

The observations herein recorded were made entirely within the area mentioned above. For the greater part, however, the observations were confined to the regions lying north of the Arkansas River and east of the paleozoic border. The greater part of the field work was done in the country through which Crowley's Ridge passes. Outside the area treated in this report, that is outside of Crowley's Ridge which traverses the counties of Phillips, Lee, St. Francis, Cross, Craighead, Poinsett, Greene and Clay, only such field work was done as would serve to indicate the best lines of observation, and, if possible, furnish a basis on which to correlate the various members of the sections studied in the ridge country. This will sufficiently explain the presence, in this report, of the sections at the various points along the Arkansas River, at Beebe, at Bald Knob, at Augusta and at Memphis.

No effort has been made to correlate the various subdivisions of the Tertiary in this state with the divisions recognized elsewhere by other observers. Such correlation would be premature and would be authentic only after a very extended and careful study of the whole Tertiary area of the state, while our observations have, of necessity, been limited in area even for the state of Arkansas. It must suffice to say that the investigations made show that the Tertiary series included within the scope of this report belong to the Eolignitic of recent writers, and that possibly the Jacksonian group, heretofore considered to attain its most northern extension at Helena in Phillips county, outcrops in the

northeastern portion of Clay county and appears at many intermediate points. Its northern limit must, therefore, be extended to the Missouri state line, and possibly beyond—a distance of about one hundred and forty miles.

One other general conclusion is deserving of mention here: Whatever distinctions or divisions are, in the future, to be recognized within this area must be based upon stratigraphic and petrographic rather than upon paleontologic data. The paucity of fossils remains in all fossiliferous divisions, except in what has been herein tentatively denominated the *Ostrea* bed of the St. Francis county sections, and the dearth of such remains in most of the strata which have been recognized as Eocene Tertiary, chiefly from lithologic and geographic data, preclude a classification based largely upon their faunal contents. As has been hinted in the foregoing remarks, the facies of the fauna which has been discovered and studied warrants the correlation of the lowest of these beds with the Claibornian.

CHAPTER II.

GEOLOGIC SECTIONS IN AREAS OTHER THAN CROWLEY'S RIDGE.

Sections on the Arkansas River.—The Arkansas River divides the Tertiary area of the state into two subequal parts of which the southern is somewhat the larger. Along its course, at various points between Little Rock and Pine Bluff opportunity is presented to study the stratigraphic relations of the various Tertiary strata, and at some especially favorable localities to study the relation of the Pleistocene to the Tertiary. At certain of the highest points along the bluffs of the Arkansas River, notably at Red Bluff, White Bluff and at Pine Bluff, in Jefferson county, the south bank of the stream exposes strata of Tertiary age and in one of them the lowest Tertiary beds occur. At Red Bluff and at White Bluff the entire sequence from a marl bed of Claibornian age to the Orange Sands is presented. Inasmuch as the Pine Bluff section is some sixty miles from the western limit of the Arkansas Tertiary and the other two sections are but little less than that distance they are here introduced for the

purpose of comparison with others made in Crowley's Ridge, some seventy miles farther to the east and from forty to fifty miles farther north, in St. Francis county.

Section at Pine Bluff, Jefferson county.—At Pine Bluff the last considerable bluff along the lower Arkansas is to be seen. From that place to the mouth of the river the stream flows through a region but little elevated above its flood plain which is composed of Pleistocene and recent alluvial materials. At Pine Bluff the top of the south bank is about 233 feet above mean tide in the Gulf of Mexico, and is, therefore, higher than any other land between that point and the Mississippi. At low water a section forty feet thick is exposed, but at the time the observations were made there was to be seen a section of only about thirty feet, but it is a very instructive one so far as it goes.

Section at foot of North Beech Street, Pine Bluff, facing north.

Plate II., Figure 4.

Bed	Ft.		Total.
1.	1.	Humus, light colored and silicious. Scattered throughout are occasional pebbles, waterworn and well rounded; all very small..................	1
2.	5.	Light colored yellowish clay, much resembling loess, containing abundant nodules of limonite. This member weathers into vertical faces. Roots of plants penetrate it to a great depth..	6
3.	1½.	Blue carbonaceous clay. This is apparently an older land surface. Intermingled with the clayey carbonaceous laminæ are lumps of light brown carbonaceous clay. This member appears to be by oxidation the chief source of the coloring matter of the succeeding one.............	7½
4.	8.	Arenaceous clay, usually of a light yellowish color, with an irregularly disseminated and sometimes cross-bedded layer of ochre in the upper portion. The surface becomes somewhat indurated on exposure..	15

5. 1. White, usually vitreous, sand; discolored in patches by iron oxide. This member is not of uniform thickness throughout the bluff and occasionally it almost entirely disappears. It is also sometimes thickened into pockets two or three feet deep. The surface is somewhat indurated and forms miniature overhanging cliffs.................. 16

6. 2. Soft sand, upper layers yellowish, the remainder white. In vertical sections this member weathers rapidly and leaves the overlying stratum as small overhanging ledges, which, however, soon fall of their own weight. This layer contains a few well rounded and waterworn chert pebbles, less than one inch in diameter... 18

7. 12. Very fine whitish or light gray clay, becoming indurated on exposure; contains numerous rather large grains of vitreous sand. Towards the bottom this member presents, characteristically irregular patches of a yellow or reddish colored and more sandy clay................................ 30

The total section exposed is from three and a half to four miles long. Slight modifications of this typical one may be seen at divers points. At the foot of North Elm Street, some 600 feet farther west, the last named member, number 7, passes into a coarser clay, almost a sandstone, much more indurated, and so oxidized that the color is red or dark brown.

Correlation.—It is probable that, at this point, the stream is eroding beds which are, with the exception of the last member, of Pleistocene age. These beds overlie or abut against Tertiary strata of the age of the Orange Sands, that is to say, strata of the age of the variegated sands which normally underlie, when both are present, the gravel beds of the region. Number 7 of the section it seems, must be correlated with the Orange Sand strata of the Brump's Bayou section given below, and is therefore Tertiary. The correlation of the remaining members with the Pleistocene is based upon the heterogeneous character of the materials entering into their structure, upon the vertical distribu-

tion of the small and well rounded chert pebbles, upon the intimate admixture of sands and clays in patches indicating that they have been derived, often in masses, from strata older and not far removed, and upon the fact that below the gravel bed, which surmounts the party-colored and cross-bedded sands in Arkansas, chert pebbles have yet to be found in Tertiary strata.

Section at Brump's Bayou.—Along Brump's Bayou, a mile west of North Beech Street, Pine Bluff, from 300 to 1500 feet south of the river bend, the lowermost sands of number 7 of the above section appear well developed and present the usual constant petrographic features of the variegated Tertiary sands of the region which are more fully described beyond. Here there are exposed some twenty feet of strata which are, for the most part, older than any seen within the limits of the city of Pine Bluff.

Brump's Bayou Section.

Bed	Ft.		Total.
1.	1.	Sandy humus	1
2.	8.	Arenaceous light yellow clay, with occasional patches of ochre as seen in the Beech Street section No. 3	9
3.	1.	Brownish, indurated sandstone forming a ledge on weathering; stratified, well laminated and having a slight dip to the north	10
4.	5.	Cross-bedded, laminated, yellow and brick red sands. This member is not to be seen throughout its total thickness since it passes beneath the water level of the bayou	15

From observations made at the water's level in Pine Bluff and along a small bayou in the eastern part of the town it would appear that the yellowish and reddish sands of this section underlie a great part of the region adjacent to the river and perhaps extend far away from it. They are commonly reached in the wells dug in and about the city. It is this member, which yielding rapidly to the corrasive action of the stream, causes the caving of the banks which so long threatened the very existence of Pine Bluff and which has not yet been entirely controlled.

A feature worthy of more than passing remark is the ab-

sence from these beds of any considerable quantity of the common chert pebbles of the region, the near presence of which to Pine Bluff is a matter of doubt. In only two members of the section do they occur, as above noted, and these are all small. There is no known outcrop of these gravels within several miles of the city and where they exist they occur only on land much higher than that on which the town stands. No bed of chert gravel is to be seen in the sections made along the river below Little Rock.

Section at White Bluff.—This locality is in Jefferson county, on the south side of the Arkansas River, township 3 S., 10 W., west half of the southeast quarter of section 19, and the northeast quarter of the northwest quarter of section 30. The total length of the section exposed at this point is about four miles, but the sequence varies but little from that given below. The section recorded was observed four hundred feet west of a deep gulch which cuts through the entire series at right angles to the face of the bluff, directly opposite the house of Mr. J. Wallace at White Bluff landing.

Section at White Bluff on the Arkansas River.

Bed	Ft.		Total.
1.	1½.	Light colored, silicious humus, supporting a scanty vegetation. It has occasional small chert pebbles scattered through it..........................	1½
2.	12.	Light colored clayey sands, becoming yellowish and passing to reddish below; conspicuously laminated..	13½
3.	20.	Light blue sandy clay, homogeneous and regularly stratified. Becomes tough and indurated on exposure..	33½
4.	½.	An irregular layer of carbonaceous clay, not continuous across the section, often thickening to three feet..	34
5.	50.	Light blue stratified clays, with some sand, with numerous pockets of sand, usually white, but often yellowish to brown..........................	84

6. 15. Soft ferruginous sandstones, fossiliferous, containing *Corbula alabamensis, Natica, and Voluta*. These sandstones are stratified and dip 15°, west of south 66°. The fossils are rare, and are mainly at the bottom of the section.............. 99

7. 18. Bluish clay, stratified, with occasional masses of soft, coarse sandstone scattered throughout. This member has the same dip as the preceding. 117

8. 3. Very hard sandy marl, weathering into nodules which are hard and round, abundantly fossiliferous, but showing only lamellibranchs and gasteropods as casts and not recognizable. The upper limit indicates an ancient weathered surface. This member is exposed at only a single point near the middle of the bluff, at the water's edge, and is there a lens, becoming lost under No. 7 a few feet away in either direction.. 120

9. 4. Bluish, fossiliferous, sandy marl, laminated, with abundant scales of muscovite (mica) between the laminæ. The fossils are *Venericardia planicosta*, Lam., *Cytherea nuttalli*, Conrad; *Corbula oniscus*; *Pseudoliva vetusta*; *Turritella carinata*; *Ancillaria subglobosa;* and abundant *Dentalium turritum*.* Sharks' teeth are abundant in the lower portion of this stratum 124

10. 1. A blue black fossiliferous clay, only one foot exposed above water level. This member contains *Venericardia planicosta*; *Pseudoliva vetusta*; *Turritella mortoni*; and *Corbula alabamensis*, Lea 125

Marl beds.—The marl beds, numbers 9 and 10, outcrop

*A portion of the collection made at this locality was sent to Dr. W. H. Dall, of the U. S. Geological Survey at Washington, who recognizes the following forms among others: *Nucula ovula*, Lea; *Leda*, 2 species, fragments; *Turritella arenicola*; *Turritella perdita?* Conrad; *Fasciolaria oweni*, Dall; *Cylichna jacksonensis?* Meyer; *Macron*, *Sp. Indet.* It should be remembered that Dr. Dall's *Fasciolaria oweni* is a new name proposed by him for the species figured as *Fusus* in Owen's Second Report on a Geological Reconnoissauce of Arkansas, Plate IX, Figure I. There is substantial agreement that the beds in question are lower Eocene.

but twice in the whole section observed and these outcrops are an eighth of a mile apart. Much of the base of the cliff at the west was obscured by a heavy talus, but these beds probably extend under it for the whole distance. At one point the beds outcrop in the river and form a bar which occasionally obtrudes itself above the water's level. Neither of these beds of marl erodes as rapidly as the clays and sandstones above them and this fact serves to explain their presence as a bench at the level of low water and also explains the fact of this member forming the bed of the stream in this locality. At the mouth of the gulch mentioned above both layers of shell marl, that is numbers 9 and 10, are well exposed; here, also, there is a north dip of from 10° to 15°. Abundant fossils, chiefly *Turritella carinata* and *Venericardia planicosta* occur at this locality, but the greater part of the fossil material was comminuted and indeterminable.

Economic value of the marl.—There have been several trials made of these marls at different times, but if the applications have been properly made, it does not appear that they have any real agricultural value. The ingredient of chief value is the carbonate of lime which is present in the shells contained, but in too small quantity to warrant mining or otherwise obtaining this marl for use as a top-dressing for soils.

Changes in the river.—Since the date of Professor E. T. Cox's visit to this White Bluff section in 1859,* very considerable changes have occurred in the course of the river at this point. Near the upper extremity of the exposure an immense sand bar has been formed which is now covered with a strong growth of cottonwood, serving to deflect the current to the left bank and to permit the accumulation of a talus more than thirty feet in height. This obscures the sequence of the strata at the bottom of this section and it is only at points below, like that at the deep gulch, that they can be seen.

The Tertiary gravels absent.—It is worthy of note that the gravels of the Orange Sand do not occur in the White Bluff section. With possibly the exception of the second, third and fourth, all the members of this section below the immediate sur-

*See Owen's Second Report of a Geological Reconnoissance of Arkansas, 1860, page 152.

face are of Tertiary age. That this absence of gravel is to be accounted for by a somewhat greater erosion at White Bluff is probable, but yet, it is to be remembered, that locality is but a few feet lower than Redfield, a small village on the Little Rock, Mississippi & Texas Railway, some seven or eight miles to the northwest. The top of White Bluff has been determined, conjointly by the U. S. Coast and Geodetic Survey and the Geological Survey of Arkansas, to be three hundred feet above mean tide on the Gulf of Mexico. Redfield is 306 feet above the same datum. Though wanting in this section the chert pebbles form a very heavy bed at Redfield and less heavy ones on the tops of all the higher ridges crossed in going from Redfield to White Bluff. The nearest point to the river where the beds of chert pebbles were seen in place is about three miles from White Bluff. The bed of the deep gulch mentioned above contained an abundance of chert, derived from the lands higher up, and an occasional piece of sandstone, derived, no doubt, from the adjacent ferruginous Tertiary sandstone; at all events the contained fossils were identical with those found in the sandstones in place. The abundance of the chert pebbles in the bottom of the gulch indicate the distances to which they may travel under suitable circumstances and renders it highly probable that considerable erosion, for this region, is indicated by their absence in the White Bluff section. Redfield is near the eastern limit of the gravel beds, and is built on a gravel ridge. All the exposures of the gravels here were in undisturbed condition, were crosss-bedded and irregularly stratified in the same manner as is usual in other parts of the state.

The section at Red Bluff.—There is an instructive section at Red Bluff, Jefferson county, in 3 S., 11 W. the northeast quarter of the southeast quarter of section 12. At this locality there is exposed a section about five eighths of a mile in length; the highest point, where the section was observed, is 276 feet above mean tide level. It is at the ferry which is half a mile east of the western limit of the exposure. The section is best exhibited in a gulley which enters the river at right angles to the face of the cliff. All the strata seen are horizontal.

The Section at Red Bluff.

Plate I., Figure 3.

B. d	Ft.		Total.
1	½.	A light colored, thin and very sandy humus, sustaining scanty vegetation. It consists of a very fine sand with occasional chert pebbles a half inch in diameter................................	½
2	2½.	A clayey sand layer, very soft, light yellow in color, becoming darker below. Small nodules of limonite are abundant..............................	3.
3.	½.	Dark, carbonaceous, earthy clay, with much less sand than the member above, thinning out or thickening irregularly. This member has the facies characteristic of an old humus...............	3½
4.	4.	Mottled sands and clays, light yellow and brick red colors predominating. This member is irregularly stratified and contains an occasional small pocket of white sand...........................	7½
5.	10½.	An irregularly bedded and indurated sandstone, forming a vertical and jutting face, thickest and hardest one hundred feet west of the ferry. It exhibits, on its upper surface, considerable weathering, evidenced by potholes, ridges, etc., which weathering occurred previous to the deposition of number 4 of this section. The lower portion of this sandstone is more regularly stratified and is of a brick red color. Detached masses of several tons weight form a considerable talus at one point on the bluff. On splitting open some of the smaller of these masses, pockets of pure white vitreous sand were found in them together with scattered nodules of soft and very bright yellow, or even red, potters' clay. Some of the layers of this member, notably the upper, contained many irregular tubes filled with fine white sand. These tubes, as well as the weathered surface of the large detached masses,	

are exceedingly hard, the matrix consisting of a much oxidized manganiferous iron cement...... 18

6. 8. Soft yellow to reddish sands, with bluish and yellowish masses of potters' clay. Below, this member becomes hard and intensely red......... 26

7. 20. Dark to blackish clay, with a little sand, quite homogeneous and fine throughout; regularly stratified and containing much selenite. This mineral is unusually present as crystals, mostly star shaped, the acicular processes radiating from a common center. They are often several inches in length though generally much smaller. 46

8. ½. A thin layer of dark brown, fossiliferous sandstone, with indeterminate fossils, indurated, jutting out in vertical sections as a thin ledge; containing much iron oxide which gives the rock its dark color.. 46½

9. 23. A lighter bluish clay, with some sand; contains numerous small needle like and stellate crystals of selenite, especially abundant near the bottom of the exposure.. 69½

At the bottom of the bluff, on the surface, was found a mass of silicified wood, belonging to the dicotyledonous genus *Laurinoxylon*, or so closely resembling it that Professor F. H. Knowlton, who has studied the specimen, is unable to separate it from that genus. (See Chapter XXVI. of this volume). The material came from the Orange Sand gravels which are found a short distance away. The mass weighs twenty-five or thirty pounds and could scarcely have been brought down the river by any natural cause nor could it have been transported far from its original position in the gravel beds.

The marl bed.—The Eocene *Ostrea* bed, or shell marl, which usually underlies this member of the Tertiary in all Arkansas outcrops is to be seen at low water near the west end of this bluff. Close by the point of the above section a nodulous sandy marl, similar to that at White Bluff, and having the same fossils, was observed, but its stratigraphic relations could not be

determined because of the very heavy talus. It is thought that this marl bed is not quite horizontal in any portion of the region examined from the fact that it is seen at times rather high up in sections, and again it occurs only as lenticular masses in the bottoms of streams and gullies. It is not a constant member of either this section or of that at White Bluff, appearing only at points in them.

The absence of pebbles.—As in the preceding two sections no Orange Sand Tertiary gravels appear in this. The first member contains a few very small pebbles, mainly of chert, but they have been brought to this place from some distant locality. Back from the river, on ridges similar in all respects to those near White Bluff, except that they are a little lower, bleached gravels outcrop in the banks of streams and on the surface, in rather thin irregularly stratified layers. In these places the gravels, when bleached, are superposed on a light colored clay, the upper portion of which contains many chert pebbles, some of which are of very considerable size, but none attain the dimensions of similar gravels about Little Rock and other points on the western limit of the Tertiary. The point nearest to Red Bluff where these beds are to be seen is about three eighths of a mile back from the right bank of the river on the top of the ridge of which the bluff is a cross-section. Between this point and the bluff the underlying clayey subsoil contains a very few small pebbles.

Brick clays.—Near the bluff and somewhat below the level of the top of the ridge the underlying clays of the higher portion form the surface soil. Though somewhat sandy, and very light colored, these clays have been used in the manufacture of bricks. The brick, as shown in the abandoned kiln, were soft and where exposed to the action of the rain and the heat of the sun rapidly disintegrated and became a fine clayey sand. It was impossible to determine whether this was due to the unsuitable character of the soil or clay, or to poor burning. In most similar sections the clay is unsuited to the manufacture of the best quality of bricks unless it be properly tempered.

Comparison and correlation.—By comparing the section at

this point with that at White Bluff, it will be noted that the blue clays are probably identical and that the stratigraphic sequence at each locality is practically the same. Such slight differences as appear are probably due to purely local causes which have resulted in modifications of strata which are genetically the same. But the differences between these strata and those that appear in the section made at Pine Bluff are equally patent. The upper members of the two former sections are entirely wanting in the latter, which fact finds a probable explanation in the relative amounts of erosion to which the two regions have been subjected. It is also probable that the character of the strata observed at Pine Bluff is determined largely by the manner in which the materials which contribute to the formation of the various members exposed at that place have been laid down. Those materials are almost solely of Tertiary origin, indeed, in some places simulate a Tertiary facies, but have been essentially modified by complete admixture and redisposition. In the most eastern section, therefore, the chronologic sequence of Pleistocene and Tertiary strata is much less regular or can not be made out at all. In other words, uniformity in structure and in the relations of the different members is much less marked than it is between sections taken nearer the margin of the Tertiary area.

CHAPTER III.

GEOLOGIC SECTIONS IN AREAS OTHER THAN CROWLEY'S RIDGE.—*Continued.*

The section at Beebe, White county.—About sixty miles north of the Arkansas River localities just mentioned, near the village of Beebe, in White county, in township 5 N., 8 W., southwest quarter of the southwest quarter of section 5, there is exhibited a very instructive section in a shaft sunk to reach Eocene shell marls for commercial purposes. The locality is on the farm of Mr. Cyrus Heller. To the section as shown in the shaft there is added the record of a well driven a few hundred feet southwest of it. The position of the section near the

western limit of the Tertiary area, which is less than two miles away, renders it of exceptional interest.

The Beebe Well Section.

See Plate II., Figure 2.

Bed	Ft.		Total.
1.	1.	Humus	1
2.	10.	Whitish sandy clay, becoming red nearer the bottom. From the middle downwards occur a few chert pebbles, the largest of which are from two to three inches in diameter	11
3.	4.	Hard red clay, containing very fine sand	15
4.	13.	Light colored, stratified, sandy clays, with abundant white chert pebbles and rarer white sandstone pebbles. These begin to appear about the middle of the member	28
5.	1.	A thin layer, from six inches to one foot in thickness, of comminuted shelly, clayey matter. This member is commonly found overlying the shell marl of the region round about the town. Fragments of *Dentalium*, but too much broken for specific recognition, were seen	29
6,	35.	Blue, clayey marl, similar in all respects to that above described, at White Bluff, on the Arkansas River. Abundant broken marine shells, with occasional perfect ones, were found; among them were *Venericardia planicosta*, Lamarck; and *Turritella carinata*, Say. Small pockets of green sand occur throughout this member which lies unconformably on Carboniferous rocks and concludes the Tertiary series at this point	64
7.	47.	Soft, blue, argillaceous shale of Carboniferous age.	111
8.	?	Hard, white sandstone, drilling with great difficulty and penetrated but a short distance. This is the Carboniferous sandstone of the region to the west	111+

Paleozoic sandstones.—The sandstones of the lower portion

of this section outcrop in massive ledges on the ridges about two miles northwest of Beebe, and against these the Tertiary clays and sands abut. Extending for some distance west of the town, along Bull Creek Bayou, the Tertiary fills an embayment which represents an ancient estuary. Along this ancient estuary Bull Creek runs, crossing an occasional low ridge of the Carboniferous sandstones and shales, but for the most part it is engaged in re-excavating the soft Tertiary materials which fill the old estuary. These ancient estuaries are common along this paleozoic scarp and the Tertiary strata are to be found extending far up toward their heads. Many of them, as here and at Judsonia and Bald Knob, are occupied by streams now engaged in the work of re-excavation. Along Bull Bayou the Tertiary strata may be traced with certainty. They cease to appear at a point about four and a half miles from Beebe. The valley of the upper portion of the bayou is flanked on either side with massive, hard, red sandstones. Usually the exposed face of these sandstones is coated with a thin deposit of manganiferous iron oxide, which appears to be characteristic of them wherever they occur and have been for any considerable time exposed to atmospheric influences. At a bridge over a small stream which flows into Bull Bayou about two and a half miles north of Beebe, the sandstones outcrop as an abrupt face fronting south. They here constitute one of the many smaller parallel Carboniferous ridges which give its peculiar facies to the topography of the region. In the roadway the rocks present a dip of quite 11° in a direction 40° east of south. A less prominent ridge is to be seen at a point half a mile further south which marks the south face of a seaward cliff against which abut and partially over which spread the Tertiary sands and clays of the region.

Correlation.—The first four members of this section are correlated with the Pleistocene. The basis for this reference is the evident rearrangement of the materials entering into their composition, the vertical distribution of the chert pebbles, the absence of perfect stratification down to the fourth member of the section, and the petrographic characters of the soils themselves which is the exact counterpart of sections elsewhere shown to be

entirely derived from sands and clays of Tertiary age. The paleontology of the remaining members places them in the Eocene, and specifically in the Clabornian.

Soils and brick clays.—The surface soils and clays of this region differ in some important respects from the soils farther to the east and within the typical Tertiary area of the state. They are rather more sandy, less heavy, and show those other differences which may be expected of soils derived from a different class of rocks. They do not appear to be any more fertile and not so well suited to the production of cotton as are many of the Tertiary soils in other portions of the state. A fair notion of their character and value may be gathered from a study of them made on North Main street in the village of Beebe, where an opportunity was afforded by excavations in Essig's brick-yard. The section gives only the upper members of the soil series, but it is characteristic so far as it goes.

Section at Essig's Brick-Yard, Beebe.

Bed	Ft.		Total.
1.	1.	Light colored silicious humus........................	1
2.	2½.	Light colored, yellowish clay, with some sand, penetrated in every direction with the roots of grasses and other plants. This member contains abundant small nodules of limonite, from half an inch to two inches in diameter..................	3½
3.	3.	Blue clay, hard, mottled and streaked with reddish and brown patches. The limonite of No. 2 increases in abundance and in the size of nodules in this layer, of which but three feet was exposed. In a cutting in the road half a mile farther north this layer is five feet in thickness, and is succeeded by party-colored sands. No roots penetrate it....................................	6½

For the manufacture of bricks the blue clay of the section, tempered with the yellow subsoil, is chiefly used.

Chert gravels absent.—In the various cuts of the region about Beebe, both natural and artificial, in which the sands and clays were studied, no chert beds were observed, nor even on the

higher lands about Bull Bayou was there to be seen a single exposure or sign of the waterworn gravel. This is of interest, for both to the north and the south, in the region about Little Rock and at numerous intermediate localities these members of the general section are always to be seen, often in great quantities.

Chemistry of the Beebe marl.—A sample of the slate colored Beebe shell marl, taken at a depth of about sixty-three feet, was analyzed by the Geological Survey. The following is its composition:—

Analysis of Beebe Marl.

An analysis of this marl dried at 115° gave the following:

Silica and matter insoluble in concentrated hydrochloric acid	73.26	per cent.
Phosphoric acid	trace.	
Iron (Ferric) oxide, Alumina,	10.02	" "
Lime	5.45	" "
Magnesia	1.05	" "
Potash	0.70	" "
Soda	0.73	" "
Loss on ignition	10.59	" "
Total	101.80	" "

Water at 115° in the air-dried soil, 4.74 per cent.

NOTE: This marl contains a large quantity of iron and organic matter. The "loss on ignition" represents carbonic acid, organic matter, and water.

It will at once be seen that this marl does not possess any great value; nevertheless it might be used locally, as a top-dressing for grain and clover, with possibly paying results, especially so in a clayey and wet soil. The lime contained is almost wholly due to the presence of the comminuted marine shells but these are not abundant. It is evident that the average percentage of lime in large lots will be far below that which should be found in a good marl. This percentage is as shown in the analysis, but 5.45, and some other and richer source of this compound would give more satisfactory results in the case of such stiff clays or soils as require its use. It is im-

probable, therefore, that these marls will posses any real mercantile value.

Section at Bald Knob, White county.—Perhaps the most interesting section to be seen on the western limit of the Tertiary occurs at Bald Knob, White county, in a quarry of Carboniferous sandstone. The locality is in 8 N., 5 W., southwest quarter of the southwest quarter of section 17. Here is a bold cliff of Carboniferous sandstone abutting against and lying upon which are to be seen the uppermost members of the Tertiary of this region. See Plate III., Figures 2 and 3.

Quarry section.—In the extensive quarry, a few hundred feet east of the railway station, the Carboniferous sandstones are exposed to a thickness of about thirty-five feet. The upper strata are thin, varying in thickness from two inches to as many feet. The freshly exposed vertical face of the section presents a variegated appearance, in which above, brown, red and purplish colors predominate; below they become yellowish, more massive and grade through grayish white to a white, very hard, compact, and fine grained rock with conchoidal fracture. It is, perhaps, needless to remark that all the colors, except the white, result from superficial oxidation. Below, the strata thicken to eight or ten feet, and the jointing, so conspicuous in the uppermost strata, is not apparent save where blasting has detached large masses of rock and discloses the faces of the joints discolored by manganiferous iron oxide. In some places in the quarry joints traverse the rocks for long distances and vary from three inches to twice as many feet in width. In many places where careful examination was made the approximated surfaces of these fractures showed the slickensides so characteristic of regions of orographic movement. These fractures extend into the quarry at right angles, or approximately so, to the face of the cliff and are filled with mottled clays and sands containing many small water-worn and rounded sandstone pebbles and a few chert pebbles.

In the west end of the quarry, on the strata forming the floor, the dip is 4°, in a direction 21° south of west; at the east end the dip increases to 10°.

Topography.—All the higher land about Bald Knob is com-

posed of ridges and hills of this sandstone which outcrops west of the line of the railway. As at Beebe, there is a series of scarps each somewhat higher than the last as the outcrops are traversed in succession toward the west. At certain points these hills attain a height of from seventy-five feet to one hundred feet above the elevation of the quarry. At a point about half a mile west of the village the road passes over a scarp of this sandstone which is very dark brown, quite porous and showing other evidences of disintegration. An occasional piece of conglomerate was found, the cementing material being iron oxide, the pebbles of which are mainly silicious or cherty and in other respects resemble those so commonly found in the pebble beds of the Orange Sands; it is probable that they are the local representatives of the Orange Sands other indications of the near presence of which are wanting. The outcrops of sandstones on these hills show every evidence of having been long subjected to the action of atmospheric forces and differ, therefore, in a marked manner from the more compact and very hard flinty sandstone in the quarry.

Well sections at Bald Knob.—At points from twenty to three hundred feet from the sandstone scarp, and indicated in figure 2, plate III., are several wells, which were examined. These all penetrate strata which are, at the lower part, of Tertiary age, and extend downwards to a depth of from twenty to forty feet. Water obtained below the latter depth is not potable. In none of these wells have the sandstones of the quarry been found but only clays and sands referable, so far as the first two members of the section are concerned, to the Pleistocene the bottom one only being regarded as of Tertiary age. The relation of all parts of the various sections is shown in figure 3, plate III. West of the quarry, on the hills, no outcrops of strata referable to the Tertiary occur save the small areas of cherty conglomerate which are believed to represent the Orange Sands, as indicated above. But near the village and south of it is a sluggish stream, Overflow Creek, which occupies an ancient estuary. So that the bottom of the wells may fairly be taken as entering into Tertiary sands. The correlation of the two upper members of the follow-

ing section with the Pleistocene is made on substantially the same considerations as those which determined the reference of similar strata at Beebe to that epoch. The well section is as follows:

Bald Knob Well Section.

Bed	Ft.		Total.
1.	2.	Sandy, light colored humus, supporting a fair vegetation	2
2.	8.	Dark and sandy clay, with occasional sandstone cobbles probably derived from the adjacent cliffs	10
3.	30.	Mottled clays, passing into fine sands, in which water occurs abundantly. The lower limit was not ascertained	40

Unconformability.—Especial interest attaches to this section at Bald Knob because it shows Tertiary strata lying unconformably upon sandstones of Carboniferous age; it indicates, also, that during the period of deposition of these Tertiary clays and sands the rocks at and about the quarry constituted a bold rocky headland which projected into the Tertiary sea. The relations of these rocks considered in connection with the character of the Tertiary strata rendered it quite probable that much, at least, of the material which was to contribute to the formation of the latter was derived from the disintegration of the former.

Soils.—In the valley of Overflow Creek, from two to two and a half miles west of Bald Knob, "buckshot" lands abound. The term "buckshot" is commonly employed by the planters of Arkansas but it is applied to at least two very different soils. In general the term is used for all soils that are lumpy, the lumps being about the size of buckshot and more or less rounded. In alluvial lands "buckshot" soils are those which break up upon weathering into small grains irregular balls about the size of buckshot. In St. Francis county and other counties farther to the north the term is in common use, but is there often, indeed usually, applied to soils which contain an abundance of small limonitic nodules so marked in the eastern half of the state. In the section on Overflow Creek it is this last character in the soils which justifies the name as applied to them. Throughout the

whole flat region of the White River valley these limonitic "buckshot" lands are the prevailing soil, and they are usually heavy and wet. They will be again discussed in connection with their origin in that portion of this report which deals directly with Crowley's Ridge.

CHAPTER IV.

GEOLOGIC SECTIONS IN AREAS OTHER THAN CROWLEY'S RIDGE.—*Continued.*

Section at Augusta, Woodruff county.—An excellent opportunity to study the clays and sands of the White River region is afforded at the town of Augusta in Woodruff county. The town is in 8 N., 3 W., and the section made is in the northwest quarter of the northwest quarter of section 31 and the southwest quarter of the southwest quarter of section 30, along the river front.

Section at Augusta.

See Plate II., Figure 1.

Bed	Ft.		Total.
1.	2.	Fine, light colored silicious humus, occasionally dark or streaked with fine black laminae, but only so in those portions about Augusta which are overflowed annually or periodically............	2
2.	½-1.	Brownish, clayey sand, somewhat indurated above but gradually becoming softer and more sandy below..	3
3.	8.	Reddish sands, with some clay, regularly stratified. Irregularly disseminated throughout the upper portion are small bodies or nodules of clayey limonite, from a fourth to a half an inch in diameter. Near the bottom the limonite nodules become very numerous, large and soft. This member weathers into an overhanging ledge-like layer wherever the following stratum is excavated..	11
4.	10.	White, stratified and cross-laminated sands, with occasional patches of clay.............................	21

5\. 2. Indurated, fine, somewhat reddish, vitreous sands with some clay. Much limonite occurs near the bottom, in clay-sand nodules........................ 23

6\. 4. Bluish-white irregularly stratified sands, with more clay than the preceding member, the sand grains are, also, somewhat coarser. Occasional pebbles of chert, like those in the Orange Sands, occur, and much less frequently small, white, well-rounded and waterworn sandstone pebbles. These latter are usually about an inch in diameter; sometimes they are flattened. The chert pebbles, while much smaller than those along the western border of the Tertiary area, are somewhat coarser than the associated sandstone pebbles and are well smoothed and rounded. This member thickens in places to five feet. From this layer was taken, also, a mass of flint weighing about three pounds. Three quarters of a mile further down stream this layer contains a considerable quantity of chert and bleached gravels 27

7\. 1. Somewhat indurated, reddish sands, becoming browner below. The upper surface of this member is very irregular, though below, it is regularly stratified and party-colored throughout. It is in all respects similar to the stratum of variegated sands which forms the vertical face of the cliff at Red Bluff, on the Arkansas River in Jefferson county..................................... 28

8\. 2. Clayey, white sands, of which only about two feet were exposed above the water level. This layer closely resembles the material which fills the fissures in the Bald Knob quarry, above described, and has, probably, a similar history...... 30

A fourth of a mile below the town of Augusta, a large clayey point projects into the river at which place only number six of the above section and the succeeding members could be

seen. The section here exhibits alluvium and humus to a depth of about four feet, under which number six occurs, appearing to graduate insensibly into number seven of the above section. At the water's edge are numerous sandstone cobbles of several pounds weight and very many small chert pebbles, some of which are but little waterworn. One piece of waterworn white sandstone was found that would possibly weigh fifty pounds.

The section given above could not be taken at any single point but is built up from facts obtained at A, B and C, Plate IV., Figures 1 and 2. The distance from A to B is nearly or quite a mile.

The ridge at Augusta.—The town of Augusta is built on the low south extremity of a ridge which rises fifty or sixty feet above White River. Cemetery Hill, about a quarter of a mile northeast of the town, is the highest land in the neighborhood, rising eighty or ninety feet above the general level. This hill is one of a series of usually little elevated sand ridges, the prevailing surface color of which is reddish, and which continue in a general north and south direction for about twenty miles. The whole consists of a sparsely wooded main ridge much cut up with transverse washes and streams and eroded on all sides. It consists almost entirely of horizontally disposed beds of Tertiary sands, with some clays of the same age, and constitutes the last evidence of the Tertiary plateau, found between the ridge and the paleozoic scarp on the west and of which Crowley's Ridge is the remnant. White River now touches the extreme southern end of this ridge, though formerly that stream, in places at least, was a chief factor in its removal. The relations of the ridge, town, and stream are exhibited in Plate IV., Figure 2.

Correlation.—From the structure of the members of the Augusta section, it will be inferred that the materials entering into the various strata are similar to those found in the towns of Beebe and Bald Knob. Of the sequence as given on a preceding page, the first six are believed to represent Pleistocene and recent deposits, and of these six the first three are recent. The two lowermost are probably Tertiary, which correlation is based

solely on stratigraphic and structural evidence. The most careful search failed to discover a fossil of any sort that would aid in the determination of the age of the beds.

Well sections in Woodruff county.—Unfortunately but very few records of the numerous wells have been kept and little information could be gleaned from them. Nearly all the wells are driven, especially after the first few feet. About Morton water is found at about thirty-five to forty feet, usually in sand. According to information kindly furnished the Geological Survey by Mr. J. Mortensen, of Morton, the wells pass, after the top and subsoil are penetrated, through a gray clay from 14 to 16 feet thick. The pipes are then driven through a sand of from thirty to thirty-five feet in thickness in which abundant water is found. At Gray's, according to information furnished the Survey by Mr. M. D. Thompson, the wells are also driven but a general section is given as follows:

	Feet.
Sandy soil, about	2
Yellow sandy clay	10 12
Sand	2-3
Blue clay	2-4
Sand and gravel in bottom	
Total	15-20

This record does not state the depth to which the sand and gravel bed is penetrated. "Buckshot" lands cap the series of soils in all the region about Gray's which border the arable ridges.

Near the southern boundary of the county, at Cotton Plant, the average well section, as furnished the Geological Survey by Mr. W. T. Echols, is as follows:

	Feet.
Soil	1½
Hard reddish clay	4
Coarse sand mixed with clay, about	4
Sand, coarse and fine	4
Fine sand	5
Total	18

It is quite evident, therefore, that none of these wells enter Tertiary strata. They, without exception, pass through strata which must be correlated with the more recent deposits of the White River valley and are mainly through the alluvial deposits of that region. The sands and gravels in which most of the wells stop may be, probably are, Pleistocene, but such correlation is necessarily one of inference.

Well sections in Lonoke county.—The Survey has received, through the kindness of Mr. W. P. Fletcher, of Lonoke, well records in and about that town which show substantial agreement with those given for Woodruff county. The record of the well at the house of Mr. Fletcher is as follows:

	Feet.
Soil	1
Lighter gray soil (buckshot?)	4
Red and mottled clays	12
Sandy clay, more sandy below	10-15
Quicksand in the bottom	...
Total	32

In a well section, distant from the above about four hundred yards to the south, there is the same section with the addition of "flint (chert) pebbles the size of a guinea's egg" though the position of these pebbles is not stated. Near the railway station in Lonoke, is a driven well 103 feet deep, in which gravel and sand were found at about sixty feet. Samples of this gravel show the coarser of it to be polished brown chert the size of hazel nuts, while the finer is coarse quartz sand. On the prairie two miles from Lonoke, a well was sunk to a depth of forty-five feet, all the way in clay and sand beds, ending in tough, mottled clay.

From information furnished by Mr. E. H. Slaughter, it appears that the water bearing gravel of the deeper wells in Lonoke county is from seventy-five to one hundred feet below the surface. The greater depth is in the region north of Bayou Two Prairie, the lesser south of that stream. From the "Pigeon Roost country" to Des Arc, the general section is as given

above, except that the gravels are reached at a depth which varies from one hundred to one hundred and twenty feet. This general section is stated by Mr. Slaughter to be measurably correct for all the region from Lonoke south to England, and from Carlisle to Argenta. "The Pigeon Roost country" lies about and between Butlersville and Hickory Plains.

Some hesitation is felt in correlating the various well sections of Lonoke county. If, however, the gravels of the lower portions thereof are in place and the overlying sands are stratified as appears to be the case, the deep wells all enter Tertiary strata. There can be little question, however, that the records of the more shallow wells simply repeat the history of those in Woodruff county and penetrate recent and Pleistocene strata. But, as will hereafter appear, they all have an important bearing on the genesis of the great alluvial valley in which they are situated.

The ridge at DeVall's Bluff—At DeVall's Bluff, in Prairie county, White River is rapidly eroding its right bank and disclosing the geology of that region. For some distance, in traveling east across the prairie lands west of the river the surface rises gradually until it is some thirty feet or more above the general plain. Then begins an abrupt descent to the river. In the east portion of the town the river has eroded its banks to such extent that a bluff not less than sixty feet in height has resulted in which may be seen the stratigraphy of the whole elevated area. There is first the usual humus or thin soil, very similar to that which occurs on the face of the prairie to the west. Under this soil is a light colored drab clay with some sand, for about twenty feet. Beneath is a thinner stratum of reddish clay, the whole being underlain by the party-colored sands of the Tertiary Orange Sands. These sands disappear under the water's level. The higher land about the bluff is doubtless underlain, for some considerable distance, with similar sands. The gravel bed seems to be wanting, a fact which is to be explained on the basis of the great erosion to which the region has been subjected. East of the river the land is all much lower and is alluvial. That this bluff, together with those at Aberdeen, Des Arc and other points of the White River have a history

quite similar to the bluff or ridge on which stands the town of Augusta in Woodruff county, is quite probable.

Jones' Island, Surrounded Hill and similar localities have a similar history though they are all considerably lower than De Vall's Bluff and Augusta. From a point a few miles east of Jones' Island there is a gradual rise until the higher lands which form the prairie regions east of Brinkley are reached. Brinkley itself, together with Goodwin, Palestine and certain intermediate points are situated on ridges of a similar character. It is not evident, however, that the Tertiary sands rise so near the surface in these last named localities as at DeVall's Bluff.

The section at Memphis, Tennessee.—It was not found practicable to make any extended examination of the Tertiaries of the adjoining states, though such an examination would help to determine the relations of the Arkansas sections to those in well-known areas. Opportunity was presented, however, for a very brief reconnoissance of the region immediately surrounding Memphis in Tennessee. The section disclosed along the Mississippi in that city and in the several railway cuts visited show only the characteristic loess and, near the water's level, the Tertiary Orange Sand gravels. There are abundant concretions and occasional land shells imbedded as fossils, in the loess, but without order of arrangement in zones or other method to indicate stratification. None of the Tertiary beds, except the pebble bed of the Orange Sand, was visible when the section was studied.

However there has recently been published*, a very valuable section of the region about Memphis, based upon artesian wells and borings of exploitation, which is here reproduced in a somewhat modified form.

Section at Memphis, by Dr. J. M. Safford.

Bed	Ft.		Total.
1.	60.	Loess. A fine, silicious, ashen or light yellowish earth, compact, forming vertical faces of forty feet or more; more or less limy, very fertile.....	60

*"The Water Supply of Memphis," by Dr. J. M. Safford, State Board of Health Bulletin, Vol. V., No. 7, pp. 98-106, Feb. 20, 1890.

2. 40. Gravel and sand—"Orange Sand." This member lies, almost entirely, between low and high water levels of the Mississippi. Its thickness varies from 20 to 60 feet.. 100.
3. 145. Dark, stiff clay, laminated in places, the laminae separated by thin layers of sand; contains fragments of lignite; there are abundant impressions of fossil leaves and occasional wedges of clay iron carbonate.. 245.
4. 800. Water bearing sand, about 800 feet in thickness. This member of the section has an occasional lenticular mass of clay. The sand is very fine above but below it becomes somewhat coarser and shows small but not abundant pebbles the size of peas..1045.
5. 45. Clay, characters not given..............................1090
6. 125. Clay at top, shading into sandy clay downward; no other characters are given........................1215.

The depth given by Dr. Safford for this boring is 1,165 feet below the surface, or 1,156 feet below high water in the Mississippi. The difference lies in the fact that in the section as adapted the average of 40 feet is allowed for the thickness of the Orange Sands and gravels.

Correlation.—The portion of this section above the gravel bed is Pleistocene; the gravels and all below represent the Tertiary. It is worthy of note that the elevation of the top of the gravel bed is much less than that of the corresponding member in the Crowley's Ridge series. It would appear, therefore, that both the gravel and the loess are laid down on a surface which represents a much greater erosion at and about Memphis than in the region west of the Mississippi. This agrees with the general deductions which are hereinafter made based upon the facts showing greater erosion in the valley of the St. Francis. That the fossiliferous Tertiaries of the two sections are also identical is highly probable, but until actual comparison of the fossil leaves has been made such equivalency is at best but conjectural.

CHAPTER V.

THE HYDROGRAPHY AND TOPOGRAPHY OF CROWLEY'S RIDGE.

General features.—Crowley's Ridge enters the state of Arkansas in the northeast portion of Clay county and extends in a general north to south direction as far as Helena, in Phillips county, where it abruptly terminates in bold bluffs facing the Mississippi River. In Clay county it is transected by the St. Francis River which there forms the boundry line between the two states. After the narrow alluvial valley of the St. Francis is crossed, in Missouri, the ridge again becomes a marked feature in the topography of the southeastern portion of Butler county, whence it is continuous to the Mississippi River, a few miles south of Cape Girardeau. The general direction for the ridge, in Missouri, is northeast and southwest. However, after re-appearing as a marked topographic feature in the east of the St. Francis valley it passes under the name of Bloomfield Ridge, from the chief town situated on it in the state of Missouri. This portion is twice again cut in two by the Castor and Little rivers. The last named stream separates it from the most northern and eastern portion, extending to the Mississippi, under the name of Commerce Bluffs. North of the Bloomfield Ridge is a smaller one, which represents it, known by the name of Hickory Ridge, a long, narrow ridge whose axis extends southwestward parallel with the paleozoic scarp. West of Bloomfield Ridge in Stoddard county, Missouri, is a detached mass of hills which reaches nearly to the St. Francis River at the point where it debouches from the hills west of the great embayment. Numerous smaller ridges, typified by the Ash Hills in the Black River country of Butler county, Missouri, and Jones' Ridge, in the Cache valley, in Greene county, Arkansas, testify to the former westward extension of the whole ridge as a unit. These ridges have a history very similar to that given above for the ridge at Augusta, in Woodruff county, Arkansas.

Inspection of the accompanying map will serve to show that the Arkansas portion of Crowley's Ridge consists of two unequally divided parts; the northern extending from the Missouri boundary to Poinsett county, and the southern extending from

the latter limit to the Mississippi at Helena. These portions differ, somewhat, in minor topographic features, but the especial difference to be noted is in the nature of the surface geology which each half exhibits. The southern half, as here limited, is narrow, and the hills attain a somewhat less elevation than they do in the northern part, that is to say, in the part north of Poinsett county. For the purpose of rendering the geology more distinct and its relation to the topography more evident, the boundary line between Poinsett and Craighead counties has been arbitrarily chosen as the limit for both the geographic descriptions and the grouping of the geologic sections.

The topography south of Craighead county.—Crowley's Ridge south of Craighead county averages from one to three miles in width, but has a maximum width of about six miles in the northern part of St. Francis county. Its minimum width is in the northern part of Poinsett county where it is somewhat less than one mile wide. This portion, therefore is a long, narrow elevation of land which rises above the general level of the country from one hundred and twenty to one hundred and fifty feet. There are no considerable streams along this part of the ridge, but there are many small ones, which are, however, little more than gullies through which the excess of rainfall reaches the lowlands. Yet these small streams and their channels exert an important influence on the general topography of the ridge throughout its entire length. At times they swell into fierce torrents cutting deeply into the soft strata and widening their beds by the formation of great land-slides along their entire length. It has resulted in the course of time that the ridge is much broken and is very irregular both as to its surface and its outline. It is nowhere flat but is very uneven and it is impossible to follow long any single ridge of its surface and be sure that one is on the real divide. All the streams of the ridge proper, with the single exception of Big Crow Creek in St. Francis county, have their channels at right angles to the main axis of the ridge. Following up one of these streams to its head one soon rises to the top of the ridge and finds himself at the head of another gulley like ravine, leading down either in an opposite

direction from the one ascended or reaching the lowlands on the same side of the axis by a tortuous course. There are not a few places where the head of a large ravine expands into an extensive amphitheatre. Such is the character of Copperas Creek in Cross county, which flows into the St. Francis near Le Vesque. This is one of the largest of the perennial streams on the east side of the ridge. And even this is often little more than a series of pools connected through the gravel beds along its channel. It is perhaps worthy of mention that all the streams which flow from the ridge in this its lower half becomes nearly dry during the long dry summers.

At the northern limit adopted above the ridge is low and narrow. Here the east and west slopes are gentle and the divide but a few feet above the general level of the lower lands to the west. Through this low point the Helena branch of the St. Louis, Iron Mountain and Southern Railway crosses the ridge, and has its roadbed along the gentle east slope as far as Paragould. At the Dee gap erosion has nearly leveled the ridge, as it has already done some fifty miles further to the south at and above Marianna where it is cut in two by the L'Anguille River.

It is worthy of especial note that the eastern slope of the ridge from Helena north to near Dee Post-office in Craighead county, is very abrupt. This side presents the best continuous geologic sections, and as compared with the western slope is the product of a later erosion. Along this east base for a great portion of the way flows the St. Francis River to whose ceaseless activity is due the nature of the east face of the ridge in its lower half. There are many places at the present time, in St. Francis and Cross counties, where this river is wearing the ridge away and helping thus to modify the topography of the region. There are no features that call for remarks in connection with the general surface of the lowland country except that it is level with a slight fall to the west toward the L'Anguille and Cache Rivers. On the east there is but a narrow strip of land between the ridge and the St. Francis and at places no such strip exists, the river washing the base of the ridge. East of the St. Francis nearly the whole country is flat and low and subject, for a great part,

to the annual overflow of the Mississippi River. Yet in both sections there are to be found many narrow and low swells most of which are so disposed that their major axis is parallel to the drainage of its region and is doubtless connected therewith.

The Topography north of Poinsett county.—The topographic features of the northern division of Crowley's Ridge are very marked and reflect in a striking degree the differences in geologic structure, or rather, perhaps, the modifications of a structure essentially the counterpart of that already presented. In the first place the ridge north of Poinsett county is very wide, often fourteen to fifteen miles, while the average width is not far from thirteen miles. A large number of considerable streams flow from this part of the ridge, the majority of which are tributary to the St. Francis. Only two streams of any size flow westward at the extreme ends of the division, both of which are called Big Creek. The more southerly Big Creek joins the Bayou Deview whence they reach the Cache in Monroe county. The upper Big Creek, near Boydsville, flows directly into the Cache after leaving the hills. The surface of the ridge from near Jonesboro northward is exceedingly irregular, being diversified with many broad valleys, narrow gullies, precipitous slopes and high hills. The main divide of this portion lies well to the west of the mass of the ridge and in most places is not more than three to four miles from its western margin. The eastern slope, therefore, is less precipitous, much longer and more gentle, the surface is much less deeply cut up into narrow and tortuous ravines, while the highest hills and most irregular surface are found on the west slope. In this respect the northern third of the ridge country is exactly the reverse of the southern two thirds. The divide is tortuous, varying in altitude, occasionally sinking well down toward the general drainage level of the country. This is particularly true of those portions crossed by the Kansas City, Fort Scott and Memphis Railway, and by the Helena branch of the St. Louis, Iron Mountain and Southern Railway. Indeed, these roads cross the ridge at the only practicable points north of township 14 north. The uncon-

solidated character of the greater part of the materials entering into the structure of the ridge renders them peculiarly liable to erosion and it results that all the streams flow through valleys of their own making, sometimes narrow and deep, sometimes broad, always labyrinthine, frequently connected, and at other times separated only by low narrow ridges. There are, however, many extensive areas east of the divide and on the top of the ridge where there are productive farms, extensive forests and a rolling country. But as the western margin is approached the valleys narrow, the hills become higher, the slopes become more and more abrupt, and soon one stands upon the crest of the ridge with the broad and heavily wooded valley of the Cache stretching away as far as the eye can see. On a bright and clear day the eastern spurs of the Boston Mountains, crowned with great forests, may be seen on the western horizon. At the foot of the ridge nearly or quite two hundred feet below flows the sluggish Cache. On these highest portions there are no farms. The highest hills are crowned with heavy deposits of pebbles and sand, the soil is poor and thin, the under vegetation is scanty and the short-leaved pine abounds. It is worthy of mention that the higher lands can be easily discerned from hills even far away by their covering of pine which is found only or mainly on these barren, sandy and gravelly eminences. Another feature that is highly characteristic is the capping of some of the highest hills with ferruginous sandstone or with conglomerate, the latter formed from the gravels of the region. There is evidence that this local induration or conglomeration has been one of the factors in determining the height of these western hills. It resists denudation while the streams occupying the valleys are digging their channels deeper in the soft underlying strata. In short all these hills, including the main ridge itself are hills of circumdenudation. The less eroded portions constitute the spurs, of varying extent, which separate the waters of each valley.

Amphitheatres formed by erosion.—There are not a few amphitheatre like areas within the main body of Crowley's Ridge which are often of great extent. They are typified by the

topography about Jonesboro and Gainesville, the former in Craighead, the latter in Greene county. These are simply extensive areas of denudation which has progressed until the lower drainage level has been nearly or quite reached. In them is to be found the characteristic clay hard-pan soil, seen at its best in the Cache bottoms, with abundant limonite nodules, some of which, as in the valley of Big Creek, north of Jonesboro, are very large, often exceeding two by three inches in diameter. These soils are wet, poorly adapted to agriculture, imperfectly drained and very "lumpy" when tilled. Most of these extensive tracts within the ridge are but little cultivated, and then chiefly along the larger streams. The highest points in Crowley's Ridge, in any portion of it, are to be found in the vicinity of Gainesville, in Greene county. Here the hills rise to two hundred and fifty feet or more above the Cache valley, and all have their precipitous faces, covered with pebbles that have descended from the top and which serve to distinguish them from all other hills in the region. A peculiar feature of this northern part of the ridge, in contradistinction from the ridge in the region south of Craighead county, lies in the fact that none of the highest hills are capped with loess clays or with any other than the characteristic deposit of waterworn gravels. Loess occurs in many places, but true loess was nowhere seen to rise as high as the hill tops. It forms, in places, a fringing blanket, ascending occasionally to within fifty or sixty feet of the top but there it stops. This fact will serve to explain some of the peculiar features in the topography of this region.

The valley of the Cache.—The valley of the Cache is low, uniformly but little elevated above the river and is, indeed, but little more than the flood plain of that stream. The nearest approach of the stream to the ridge, which it nowhere quite reaches, is in Greene and Clay counties. Its head waters are in a swampy area in southeastern Missouri, which forms a portion of the Black River valley. The arable areas are few, though somewhat more numerous nearer the mouth of the stream in the middle White River country. In this northern portion of the Cache valley the arable areas constitute slightly raised, long, or

lenticular areas, surrounded by lands under water or very wet during a great part of the year. There are occasional cypress swamps, but most of the cypress bearing area is on the east side of Crowley's Ridge. During the summer months the patches of cypress may be discerned for long distances from the hills as islands of deeper green rising far above the general level of the tops of the adjacent forests. So flat is the country of the river bottom, that near the north boundary of Clay county it seems to be a matter of indifference to many streams whether they flow into the Cache or into the Black River. Some of the surface waters find their way into both streams by the same channel.

CHAPTER VI.

GEOLOGIC SECTIONS SOUTH OF CRAIGHEAD COUNTY.

For purposes of convenient reference the arrangement of the sections in this report is geographical. They begin with the southernmost exposures studied in the vicinity of Helena, whence they are serially arranged to Clay county. They present, therefore, the stratigraphy of the ridge from its southern to its northern extemity in Arkansas. By such an arrangement it is hoped to make the special relationships of each section apparent without burdening the report with needless repetitions.

Geologic sections at Helena.—This section was made at the Big Spring, two and a half miles north of the city of Helena, on the east side of Crowley's Ridge.

Section at Big Spring, Helena.

See Plate II., Figure 3.

Bed,	Ft.		Total.
1.	3.	Light colored, sandy humus; often wanting at the summit	3
2.	80.	Loess, compact, much fissured, weathering into vertical cliffs	83
3.	90.	Orange Sands, capped with gravel, in color ranging through all shades of red, brown and yellow to white and vitreous sands. Scattered through-	

out the upper portions of this immense bed are irregular layers of bleached gravels, mostly of chert. 173

4. 2. Yellowish to drab sandy clays, with occasional pebbles.. 175

5. 20. Light slate colored, regularly stratified clays, homogeneous throughout....................... 195

6. 5. Rudely stratified, waterworn and smoothed gravels, with much party-colored sand........................ 200

7. 10. Sandy clays, with partings of pure clay bottom not exposed*... 210

The bipartite character of the loess at Helena.—At and about Helena, on the flanks of the spurs of the ridge and on the sides of the deepest ravines which everywhere give the ridge an exceedingly tortuous outline and render the topography so broken, occur heavy blanketing deposits of modified or newer loess which contain abundant fossils. By this term, used in the absence of a better one, is meant a loess having the principal characteristics of the loess as generally exhibited elsewhere, but of later deposition. It is, further, a loess manifestly derived from the older and is rearranged, usually stratified, fossiliferous, and often separated from the older loess by a well marked line containing organic matter and presenting the facies of an old humus or soil. It is petrographically finer, somewhat lighter colored and certainly less compact than its older congener. This peculiarly modified loess does not form the top of the ridge anywhere about Helena, nor does it reach to within fifty or more feet of the top. It generally abuts directly against the unmodified or older loess which forms the mass of the hills above the gravels. In deep ravines where the loess is entirely excavated, the unmodified loess often extends to the bottom of the ravine underneath the newer or modified deposits. In one or two localities the gravels are to be seen directly overlain by this newer deposit.

While this member presents the familiar facies of typical

*In the plate the scale to which the figures are drawn precludes the representation of the full thickness of numbers two and three of this section. The blank space in number two represents an omission of sixty-five feet, and that in number three an omission of seventy-five feet of the member.

loess deposits, it seems sufficiently different to warrant individual mention. From its vertical distribution, from its stratification and its texture, which is somewhat finer than that of the typical loess deposits of the region, it appears to be, in fact, a shore deposit of rearranged loess soils. Though highly fossiliferous the forms found are principally land shells, with comparatively rare fresh-water forms, though the latter are occasionally abundant. The always present and abundant calcareous nodules, loess-kindchen or loess puppets are found in great variety of form, singly, cemented together, spherical, flat, twinned, smooth, with frequent sharp projections, and always without order or law of arrangement or of abundance. They are without any sort of nucleus and are solid, so far as the breaking of many hundreds of examples can show, differing in this respect (that is, in respect to solidity) from similar concretions found in the northern loess and which are almost or quite uniformly hollow. No tendency to arrangement in zones or in groups has been noticed, though the abundance varies within rather wide limits in localities not very far removed from each other. The modified loess is here always well stratified, while the mass of the true loess is never noticeably so distinguished in this region. This is true of all deposits observed about Helena, from the top of the hill to the base, some of the exposures having weathered faces of ninety feet or more in vertical height; and in such exposures, if anywhere, weathering ought to bring out the evidences of stratification.

Great deposits of loess occur in and about Helena. In the Spanish Grant no. 2388, north of the central portion of the town, is a deposit anywhere from fifty to eighty feet in thickness. It here weathers into vertical cliffs, becomes a little stiffer and darker yellow in color, and is often sufficiently blotched with red to greatly modify its appearance. This coloration is due to oxidation, and is but a superficial coloring of the individual grains. It is usually seen near some great fissure or in faces which have long been exposed to weathering. At this locality the nature of the deposit differs somewhat, in places,

from typical loess, being a little more sandy and the sand being rather coarse.

Vertebrate fossils.—The loess is succeeded downwards, at this locality, by a stiff blue black carbonaceous clay, of fetid odor, and having likewise an occasional pocket of very fine sand. This place, which is in the rear of a dwelling, is known in the neighborhood as the place in which some mastodon bones were found. The fossils are said to have been taken from the bottom of the section at a distance of some twenty-five feet from the present face of the cliff. The bones taken out were forwarded to the Smithsonian Institution at Washington. It is believed that the greater part of the skeleton still lies buried in this clay, which is not stratified, but has the character of bog clay and is quite local in its occurrence.

Loess fossils.—The loess in this same Spanish Grant, as indeed it is in all the sections about Helena, is very rich in fossils, all of those found, with a single exception, being land shells. As in the case of the concretions there is no indication of orderly arrangement of these fossils either in point of abundance or in zones. They are scattered indiscriminately and abundantly throughout the vertical faces of most exposures, and may be obtained in great numbers in the gullies where they have been separated from the loess by the action of water. Following is the complete list of the loess fossils found at this point (Spanish Grant, no. 2388):

Mesodon profunda, Say. Abundant.
Mesodon exoleta, Binney. Common.
Mesodon elevata, Say. Common.
Helicodiscus lineatus, Anthony. Abundant.
Patula alternata, Say. Common.
Triodopsis palliata, Say. Common.
Stenotrema monodon, Rackett. Common.
Stenotrema hirsuta, Say. Abundant.
Punctum minutissimum, Lea. Rare.
Zonites arboreus, Say. Very abundant.
Zonites minusculus?, Say. Common.
Vertigo gouldii, Binney. Common.

Strobila labyrinthica, Say. Rare.
Pupilla contracta, Say. Rare.
Succinea obliqua, Say. Abundant.
Selenites concava, Say. Rare.
Gyraulus deflectus, Gould. Rare.

Of this list the last mentioned individual is the only fresh-water species found in the loess about Helena. Many of the land shells, notably the *Mesodon profunda* and *Mesodon exoleta* are very large and well preserved. Some of the latter forms are almost as large as the giant *Mesodon major* of the Tennessee mountains, but are easily distinguished therefrom by the sculpturing and height of the shell. The various species mentioned in this list are now all or nearly all living in the region about Helena.

Land-slides.—At the west end of Porter street, Helena, on the east slope of the ridge and near its base, is evidence of the numerous land-slides which have characterized the region. These land-slides suggest that the great thickness of the loess, as observed at several localities, may be due in part to the fact that the faces exposed are vertical ones possibly formed in the line of a re-excavation of ancient drainage channels. Indeed the writer believes that the general features of the topography about Helena and at most other places along Crowley's Ridge were formed prior to the deposition of the loess, which was laid upon them like a blanket of silt. The section at Porter street is as follows:

Section on Porter Street, Helena.
See Plate IV., Figure 3.

1. Humus, contains sand mixed with clays.
2. Modified (newer) loess, fossiliferous, abutting against no. 3 and containing some pebbles below.
3. Sandy loess, without fossils but with considerable sand; abundant gravel below. The line of demarcation between this member and the typical loess is very distinct, both petrographically and stratigraphically.
4. Typical loess, fissured throughout and becoming brick red below. Concretions abundant.

5. Stratified, bleached and waterworn gravels, chert abundant, some purplish quartzite. The not abundant sand is oxidized to a brick red color.
6. False-bedded, reddish sands, with some gravel. At A are pockets of fine yellow potters' clay, imbedded in red sands. This clay is local.

The older and newer loess.—Sections similar to this one may be seen along the Helena and Marianna road, the road leading along the base of the ridge near the Fair Grounds, and near the south part of the city not far from the southern extremity of the ridge. In all these places the evidence of redeposition of portions of members of the general section is clear. But most of them likewise show that the modified or newer loess always abuts against the older typical deposit, and that this older deposit has either an abundance of pebbles imbedded in its lower portions, or else that those portions were more sandy. Either class of facts has an important bearing on the general interpretation of the sequence of events, and seems to show that the waters which deposited the earlier loess at first greatly—though possibly only locally—disturbed the older sand and gravel beds on which the loess rests. In this way only could the pebbles and sand of the lower loess be accounted for. The same vertical distribution of modified loess was observed at several places on the west side of the ridge along the Helena and Little Rock public road. The lower hills and swells far out from the foot of the ridge have the modified or newer loess capping them, while the higher portions of the main ridge exhibit it as a fringing blanket. If, however, these outlying ridges, or spurs, rise higher than ninety-five feet this member will not be found on their summits. Fine exposures of typical loess clays are to be seen on this same road two miles or more west of Helena where it is filled with concretions, but devoid of fossils.

Section in Prussian Cemetery, Helena.—A most instructive, but at the same time complicated section occurs in a cross-section of a spur of the ridge as seen in the Prussian Jewish Cemetery, about two miles north of Helena. The section is illustrated on Plate IV., Figure 4. At A is about thirty feet of typical loess,

which weathers into massive cliffs as it does on the highest portions of the main ridge. At L is about eight feet of modified or newer loess, stratified and abounding in fossil land shells, the species being the same as those found at Helena and contiguous localities. At F is an irregular, sometimes thin, sometimes thick, bed of bleached chert gravel, with very coarse red sands, and here representing an old surface of erosion. Below it at E is a heavy bed of party-colored sands, rather coarse and containing an abundance of pebbles. At the extreme left of the section, at K, occur stratified and cross-bedded red sands, without pebbles, the sands being somewhat indurated. At B is a layer of fine pink potters' or pipe clay, much jointed, with extremely fine partings or laminæ of light colored pipe clay. It is followed by O, a coarse yellow stratified sand, with numerous clay pockets, below which, also, is C—D, a light slate colored clay three inches in thickness, irregularly disposed and separating O from M. The last is a fine, red, regularly and horizontally stratified sand. At the south end of the cut B dips suddenly to the south, at an angle of nearly 45°, while the main portion of the layer has a general northward dip of 5°. A second pink and slate colored layer of pipe clay, also marked B, appears at the bottom of the cut on the south half and disappears beneath it near the middle of the section. This member reappears at the extreme north end of the section shown in the cut.

It is believed that this section serves, in a certain measure, to explain the order of the events which it records. In the first place where the humus, H, is eroded entirely away, the unmodified or older loess appears, except at the very top of the section, as the underlying member. Here an eight or ten foot layer of modified or newer loess is exposed and the line of demarcation is plainly to be seen as an old surface of erosion, marked Z in the cut. This member then, simply fills an old channel or depression in the older or unmodified loess, while that member itself fills a more extensive channel excavated in the Orange Sands and gravels which form the base of this spur, and the greater portion of the lower half of the main ridge. The surface line of this more ancient erosion is represented by the irregular gravel bed

X, itself the product of a similar state of affairs. This section is one of several which exhibit the cross sections of ancient drainage channels.

Features of erosion.—The ridge about Helena, as at all other points in it, is much carved by gullies and ravines. It results from this that though the east slope is generally steep and often nearly or quite vertical, it has many spurs standing out from the main ridge. Ascending one of these ravines for a short distance, usually less than half a mile, the observer finds himself on the main ridge, which is generally heavily wooded, and stretches away to the north in a tortuous line. Projecting from the west side of the ridge are many spurs, similar to but not so high as those on the east side. These are the residua of lateral erosion, and they often extend away to the west as many as seven or eight miles. A further distinguishing character of the westward projecting spurs is that their sides are less precipitous and their channels less deeply eroded than those of the spurs on the east of the main ridge. This feature gives to the surface of Phillips county west of the ridge, a rolling appearance that it nowhere else exhibits. In short the two sides represent different topographic types, and present fairly characteristic illustrations of what President T. C. Chamberlin calls topographic old age and topographic youth, the east side representing the newer and the west side the older topography. The cause in the difference in the topography in the two sides of the ridge is principally that the Mississippi River was not long since, geologically speaking, actively employed in cutting down the eastern side of the ridge just as it is now engaged in a similar work along its left bank. The precipitate character of the east face of the ridge is evidence that the river's work has been quite recent.

Section made by Professor Cox.—An attempt was made to find and verify the section made at Helena by Professor E. T. Cox in 1859*, but the changes in the thirty years which have intervened have been so marked that it was impossible to find any section agreeing therewith. However, the sequence of strata as studied by him are here reproduced for purposes of compari-

* Second Report of a Geological Reconnoissance of Arkansas, page 413.

son. The exact position of his section is not stated in his report.

"Quaternary."

"Yellow siliceous clay	6 feet.
Marl, with fossil shells	?

At this place the marl was traversed with two vertical cracks, one inch in width and filled with sand from the stratum beneath."

"Tertiary."

"Yellow and orange sands and gravel	20 feet.
Gravel	½ foot.
Space concealed—reddish clay?	9 feet.
Plastic clay—(potters'), local	½ foot.
Yellowish and white sand, with some gravel	5 feet.
Sand and gravel	15 feet.
Space concealed	12 feet.
Bed of slough	0 feet."

The "marl with fossil shells" is doubtless the loess, but there seems to be no good reason for supposing the crevices to have been filled with sand from below. If it be remembered that the shell bearing loess, which is the modified or newer loess in this region, lies like a fringe along the slope of the ridge and that the sands often extend to a much greater elevation than the highest limit of this deposit the presence of the sand is readily and far more naturally accounted for. The phenomenon of cracking or fissuring of the loess is a conspicuous feature of it wherever it occurs on steep slopes and in vertical faces. These fissures are often many feet in length and depth. The sands of contiguous formations from points higher than these fissures would therefore readily be washed into them. These subjacent Orange Sands sometimes cap the highest ridges though they do not cap it in any part of the ridge south of Craighead county; in this region they rise, often, high up in the mass of the ridge. It is evident, therefore, from these sections alone that Professor Cox regarded all the gravels and sands of the region as of Tertiary age. In this he differs, and the writer thinks correctly,

from Hilgard who studied similar deposits in Mississippi and classed these gravels and sands with the Pleistocene.

Section exhibited by borings at Helena.—No opportunity presented itself to study these formations below the level of high water in the Mississipi, there being neither wells nor excavations of any other sort to be found. Fortunately, however, we have the results of a series of borings made by the U. S. Engineer Corps in 1880, for the purpose of determining among other things the age of the channel of the Mississippi River. These borings were reported on geologically, by Professor Eugene W. Hilgard, of the University of California.* These borings continue the Helena section well into strata of Clabornian age. Two borings were made, the first of which was started on the bluff southwest of the town and reached a depth of nearly 237 feet. The following section is compiled from the records of this well.

Record of a Boring on the Bluff at Helena.

Bed.	Ft.		Total.
1.	0.5	Loess, brownish yellow loam, non-calcareous.	0.5
2.	139.2	Loess, yellow silt, calcareous and full of snail shells and concretions. Contains crystals of green tourmaline..................................	139.7
3.	28.1	Transition stratum of yellowish clay............	167.8
4.	5.5	Orange Sand, mainly well rounded, of yellowish chert, full of casts...........................	173.3
5.	65.3	Various layers of stiff blue clay, with green sand common to most of the thin layers, the series being mainly a greensand clayey marl. The fossils contained were, besides abundant *Foraminifera* the following: *Dentalium, Ostrea, Corbula, Turbinolia, Natica umbilicata* and *Voluta petrosa*, all indicating the age of the group to be Clabornian..	238,6

The full series of fossils that were found "well preserved" is given as follows by Hilgard:†

* See Annual Report of the Mississippi River Commission, 1883, pages 485-488.
† Loc. cit., page 488.

Monoceros vetustus, Lea
Nucula magna, Lea
Natica minima, Lea
Pleurotoma lonsdalii, Lea.
Actæon lineatus, Lea
Dentalium territum, Lea
Natica magno-umbilicatu, Lea

There are besides an undescribed *Pleurotoma*, *Flabellum*, and *Retepora*. As Dr. Hilgard himself points out these fossils are Clabornian in age and hence Eocene Tertiary.

The second boring was a mile and three quarters east and a little north from the first. It began at a level 138 feet lower than the preceding and reached to a depth greater by 116 feet. The following section is adapted from the one given in the report by Dr. Hilgard.*

Section of Boring in the Bottom Lands at Helena.

Bed.	Ft.		Total.
1.	31.	Alluvium	31
2.	56.4	Fine sand, grains rounded and sharp; little mica above, below becomes plentiful in broad plates, some red some green; no tourmalines; no lignite above, but below it is abundant in grains	87.4
3.	55.3	Coarse and clean sands, with gravel, rounded but varied with quartz, carnelian, yellowish chert and occasional fragments of composite rocks; no mica; lignite grains present but not very abundant	142.7
4.	19.6	Alternating layers of coarse and fine sands, with pebbles as in number three, and the same sort of pebbles and lignitic particles	162.3
5.	27.2	Blue clay, with very fine clear and rounded grains of quartz; abundant lignite grains (Tertiary)	189.5
6.	0.2	Lignite, massive (Tertiary)	189.7
7.	16.7	Smooth blue clay, with very fine clear and rounded grains with quartz; lignite present in grains (Tertiary)	206.4

Comparison and co-ordination.—It will be noted that this

*Loc. cit., page 485.

boring made in lower grounds did not discover any fossils other than the grains of lignite. It is decidedly different from that made on the bluff. There is entire absence of the loess and other materials of undoubted Pleistocene age except such of the uppermost strata as are plainly, in part at least, derived from the adjacent hills and overspread the immediate valley as a thin surface deposit. The grains of lignite are plainly derived from some lignitiferous formation since it exists only in small grains and even these grains are not uniformly distributed vertically. Lignite grains are, however, shown to be characteristic of all members of the general section in the great trough of the Mississippi, so far as that section has been disclosed in borings made east of Crowley's Ridge.* But no such grains appear in the bluff boring. It will be seen, furthermore, that the mineralogic character of the gravels in the two borings is substantially the same. But that the gravels are equivalent is to be doubted, especially when considered in conjunction with the testimony furnished by the grains of lignite. There seems to be no room for doubting that the beds passed through in borings made in the low ground are derived from the older Tertiary beds which form the mass of the lower portion of the ridge. The petrographic character of the materials found in the lower borings is such that their origin must be sought in the adjacent deposits of known Tertiary age. They are a newer Tertiary, save the uppermost portions which are plainly alluvial. The line of contact between the older and newer Tertiary beds is therefore to be sought between the points at which the Helena borings were made. It may be regarded as well proven that the bottom borings passed through strata which abut against older Tertiary strata of Clai-bornian age. It remains then only to ascertain the age of the strata passed through in the low lands. It is believed that the facts all point to the Port Hudson as the probable age of these

*See Progress Report of the Mississippi River Commission, 1881, Appendix J, pp 139-171, and plate 4.

Also, Progress Report of the Mississippi River Commission, 1882, pp. 205-229, Appendix P.

Also, Progress Report of the Mississippi River Commission 1883, pp. 479 et seq.

These reports contain, together with the record of the Memphis section given by Dr. Safford and given on p. 28, all that is known of the strata underlying the Mississippi trough

beds. The evidence may not be entirely conclusive, but such reference seems justifiable. Aside from the great numbers of lignitic grains, the abundance of smooth blue clay, and the known geographic distribution of the Port Hudson, which extends to near the vicinity of Memphis, must be considered those statements of the Louisiana geologists who find the Port Hudson overlying "the drift," our understanding of their drift being that it is the representative of the Orange Sand. But, insignificant as it may seem, the lignite is itself a strong factor in determining this reference. While the grains may have been derived from either the Northern Lignitic of Hilgard, or from the lignite beds of the Eocene Tertiary of this region (from which it does not matter), they have certainly been deposited in strata younger than either. It would seem then to be very clear that the city of Helena lies not far from the western limit of the ancient trough of the Missssissippi; indeed, at this point the river is now probably flowing above its early Pleistocene channel.

Correlation with the Jefferson county Tertiary.—By reference to that portion of this report which treats of the sections studied on the Arkansas River in Jefferson county, and comparing them with the sections disclosed by the Helena bluff boring, it will be seen that the shell beds or fossiliferous strata of the two areas are the exact equivalents of each other, both paleontologically and petrographically. Further, that since the Helena beds are reached only by boring to a depth that is considerably below the surface of the surrounding region, which surface is itself several feet below the general level of the bottom of the White and Red Bluff sections, it is clear that the dip of this member of the Tertiary is, in general, towards the east in Jefferson county. A further comparison with the section made on Little Crow Creek in St. Francis county, indicates that this member, which there outcrops at a point much higher than the Helena beds, dips south. The exact distribution of these Clabornian strata will never be known until many carefully conducted borings shall have been made over the whole Tertiary basin. As seen above, the shaft in the section at Beebe passes through strata of the same age, but they are reached, as is to be expected from the geo-

graphic position of that town, at a much less depth than at Helena.

The loess and soils of Lee county.—About seventeen miles of the total length of Crowley's Ridge lies south of Marianna, at which point it is cut in two by the L'Anguille River. The northern portion of the ridge in Lee county is generally somewhat lower than is the extreme southern portion in Phillips county. Near the southern border of Lee county the ridge widens to nearly or quite six miles. The surface is much cut up, though none of the sections show more than the upper or Pleistocene members of its strata. The ridge slopes gradually to the west but is quite abrupt on the east throughout Lee county. At the northern end of this section of the ridge, two or three miles from Marianna, the loess caps all the hills which, however, are lower than those at Helena. Occasional patches of the newer or modified fossiliferous loess are to be seen on the road leading from Marianna to Phillips Bayou. One such patch occurs on 2 N., 4 E. the southwest quarter of the southeast quarter of section 19. The road here crosses a hill which has been excavated to a depth of about ten feet in the newer or modified loess, at which point the following fossils were found:

Mesodon multilineata, Say; *Selenites concava*, Say;
Mesodon albolabris, Say; *Triodopsis inflecta*, Say;
Mesodon profunda, Say; *Stenotrema hirsuta*, Say.

All of these shells belong to the larger forms of living land mollusca, and many of them are common in the surrounding region at the present time. Between this point and the town of Marianna the road crosses a deep ravine or gully in which there is a great deposit of a loess-like soil. That this soil presents the product of comparatively recent erosion of the typical loess admits of little doubt though no adequate cause for its very marked oxidation could be ascertained. This soil is an exceedingly fertile one and fills the lower portion of all the creeks, ravines, and gullies in this region which open to the north. Since the elevation is but little above the bottom land it is possible that the soil is one deposited from the silt laden waters of the

L'Anguille and St. Francis Rivers which, at seasons of flood, cover a vast area about Marianna, especially to the north and east. The overflowed region here extends well out towards the boundary of St. Francis county, a distance of from seven to nine miles. For all that distance the ridge has been entirely removed and the whole country is flat, wet and clayey, and but little above the general level of the St. Francis River. This latter stream formerly occupied the great bend which is now known as Cow Bayou. There are not less than two hundred square miles of country in this and contiguous portions of Lee county which are overflowed annually. The bottom lands contain much wet clayey soil, abounding in limonite, and constituting a typical "buckshot" soil. In all important particulars, otherwise than above indicated, the general features, both of surface and of soil, are the same as those in Phillips county. No geologic sections that afford information as to the structure of the county were found save on the east side of the ridge, near Phillips Bayou, which section repeats with little variation the stratigraphy of the section made at Big Spring in Phillips county.

CHAPTER VII.

GEOLOGIC SECTIONS SOUTH OF CRAIGHEAD COUNTY.—*Continued.*

Geologic sections in St. Francis county.—Among the numerous sections studied in St. Francis county but two or three are deemed of sufficient general interest to present in this portion of the report on Crowley's Ridge. The particularly interesting, if minor sections, that appear in the special report on this county, in another portion of this volume, serve solely to explain phenomena which have but a secondary interest in connection with the geologic history of the ridge and are therefore omitted from this portion of the report.

The Crow Creek—Madison section.—A section observed at the head of Little Crow Creek and along its course to a point near Madison, a distance of three and a half miles, shows the general stratigraphy of the ridge as cut from east to west. The section begins south of the Memphis and Little

Rock Railway, in township 5 N., 3 E., section 35, southeast quarter of the southeast quarter, just east of the great railway cut at Forrest City:

The Crow Creek—Madison Section.

See Plate I., Figure 1.

Bed.	Ft.		Total.
1.	2.	Light colored, thin silicious humus, supporting a strong growth of forest trees	2
2.	15.	Compact, jointed or fissured loess, weathering into vertical cliffs	17
3.	3.	Loess-like, hard, tough, jointed, reddish, and somewhat sandy clay. Probably but a local modification of the preceding number	20
4.	10.	Light colored, little sandy, jointed loess, with joints filled with a darker and tougher clay, the whole exfoliating in large slab-like pieces. This member is irregularly stratified and weathers bluish or purplish	30
5.	8.	Reddish, irregularly disposed indurated clay, reddest above, often thinning out to two or three feet.	38
6.	7.	Imperfectly indurated mottled clays and sands, very fine; colors ranging through blue, yellow and red, the last predominating. At the beginning of this member, along the zone of junction with the preceding, issue springs, and this line marks a spring zone, as a rule, throughout this portion of the ridge. The clays are further characterized by the presence of a considerable quantity of clay limonite in scattered nodules	45
7.	5.	Irregularly stratified silicious gravels, with some purplish quartzite. As at many other places throughout the ridge it is here imperfectly cemented into a conglomerate. This member contains occasional pockets of the white quart-	

zose pebbles mixed with quantities of white sand. The pebbles are well waterworn and rounded, while the sand is likewise rounded and coarse. The gravels are often bleached and are composed chiefly of chert, vitreous quartz, and hard white sandstone. The cementing matter is iron, with which is always associated a little manganese. The pebbles of this chert layer are often fossiliferous, containing abundant crinoid stems and occasional fragments of *Productus*. Two or three forms of fossil coral were also found here. Much of the gravel is of Carboniferous origin. 50

8. 3. Blue black and light blue clays, stratified, the strata separated by exceedingly thin partings of glauconite, with fine sand and very great quantities of white mica scales. This association of white mica, or muscovite, and glauconite is a constant feature at this horizon throughout the ridge in this county........... 53

9. 10. Blue, laminated, regularly stratified clays, with very little or no glauconite 63

10. 2. Cross-bedded, clayey, somewhat indurated, party-colored sands. (See remarks at the end of the section.).. 65

11. 1. Cross-bedded, party-colored, and somewhat indurated sands.. 66

12. 5. Dark blue carbonaceous stratified clays, almost lignitic.. 71

13. 5. Shell marl—*Ostrea* bed. This is an immense deposit of fragmentary oyster shells, commingled with some blue clay, very hard in place but soon crumbling to a fine powder on exposure to atmospheric influences. Additional fossils are ***Mytilus hamatoides***, ***sp. nov.*** and *Natica magno-umbilicata*. The abundant *Ostrea* is probably *Ostrea sellæformis*........... 76

14.	1.	Blue black, nonfossiliferous, glauconitic and micaceous clay, dipping north at an angle of 10°..	77
15.	5.	Glauconitic (?) sands, with fine clay partings; contains abundant fossils, among which are *Venericardia planicostata, Turritella carinata, Pseudoliva vetusta, Voluta sayana, Cytherea nuttalli, Corbula oniscus,* and *Dentalium turritum* (?) The full thickness of this stratum could not be ascertained since it passes below the water level of Little Crow Creek...............	82

Remarks on the section.—This section presents a single abnormal feature to which attention should be directed. It is quite evident that Bed no. 10 belongs to Bed no. 7 in this section, and it may be said that that is its usual position in other portions of the ridge wherever it occurs. As intimated above, this section is founded upon a sequence of strata exhibited throughout a distance of more than three miles, through a region of great erosion, and abounding in evidences of land-slides of great magnitude, both ancient and modern. That this stratum is here placed between two layers of blue clay of the same geologic age, both of which layers are older than it, is doubtless due to some such phenomenon. These party-colored sands are generally associated with the gravel beds but are often below them in stratigraphic position.

Section on Little Crow Creek, in section 36.—The Little Crow Creek section is of special interest, because it presents the entire stratigraphy of this portion of Crowley's Ridge in one vertical section in which the various members are well defined and the lines of division clearly to be seen. It is in township 5 N., 3 E., and exhibits a complete sequence through the Pleistocene and penetrating the Tertiary. It is about one hundred and twenty feet in height and is one of the best to be seen in eastern Arkansas within the Tertiary area.

Little Crow Creek Section.

Bed.	Ft.		Total.
1.	4.	Light colored, sandy humus..............	4
2.	40.	Loess, light yellow in color, splitting off in great masses, weathering into vertical cliffs.........	44
3.	30.	Light colored, unmodified loess, containing a considerable amount of sand. This represents the character of the deposition of early loess. Reddish below through the oxidation of iron.	74
4.	6.	Party-colored, cross-bedded soft sands with coarse rounded grains............................	80
5.	5.	Fine gravels, irregularly stratified, the beds consisting of chert, quartzite, and sandstone pebbles commingled with sand; contains frequent pockets of pure white and coarse sand.	85
6.	2.	Light yellowish, somewhat carbonaceous clays.	87
7.	4.	Bluish or blackish stiff jointed clays, with crystals of selenite. Its juncture with the preceding member forms a zone of springs, not only at this point but at numerous places on the east side of the ridge...........................	91
8.	15.	*Ostrea* bed, made up of fragments of *Ostrea sellæformis*. This stratum is divided by two blue clay partings, into three layers, the upper of which is six and the lower fifteen inches in thickness. It is, however, mainly a great mass of *Ostrea* shells which are usually much comminuted, though entire specimens from 8 to 12 inches in length were secured. These shells are imbedded in a matrix of blue clay.* Near the middle of the exposure this bed thickens into a very considerable pocket of shell marl..	106
9.	2.	Compact, stiff, blue clay	108

*Upon many of the shells and intermingled with a mass of them were found attached large numbers of a *Mytilus*, for which, from its close resemblance to the form common on the recent *Ostrea virginiana* of the eastern coasts, the name of *Mytilus hamatoides* is proposed. The species is described elsewhere in this volume.

10. 5. Horizontally stratified blue clay with thin partings of glauconitic fine sands, with abundant but scattered fossils identical with those given in the preceding section. Near the middle of the section this member thins out and the depression thus caused is filled by the *Ostrea* bed above mentioned, as a pocket 113

11. 3. Blue sandy clay, stratified, the strata separated by thin layers of glauconite with abundant mica scales. Passes beneath the surface of the water 116

The oyster bed.—The *Ostrea* bed is divisible, on a color basis, into two portions of which the upper one is the more highly oxidized and of a deeper red color. Of course the division is not significant of more than a brief chronologic period and is not susceptible of such interpretation as would widely separate the two halves of the bed. Yet there must have been total extinction of the oysters of the region included in the area containing the double bed for a considerable period. But since the species are the same, the period is too brief to be of any assistance in determining the separation of the two members and they are therefore considered to be of practically the same age.

Extension of the Little Crow Creek section.—Some distance from this place, perhaps half a mile to the east, a well has been sunk by the Memphis and Little Rock Railway into strata which, lying but little above the general level of the floor of Crow Creek, represent the portions of the lower members of the above section hidden by the waters of Little Crow Creek. The beds disclosed are the following:

Railway Well Section.

Bed.	Ft.		Total.
1.	2.	Surface soil, sandy in nature, with some clay and a few pebbles derived from the adjacent hills....	2
2.	10.	Bluish or black clays, with very little sand, with which is some glauconite..............................	12
3.	3.	*Ostrea* bed, indicated by numerous fragmentary	

masses of solidly cemented *Ostrea* shells, in the material around the curb............................ 15

4. 30. Sands and clays, glauconitic, fossiliferous, the fragmentary remains being identical with those found in the same member in the section above.. 45

This well section therefore extends the Eocene downwards about twenty feet further than the natural section on Little Crow Creek.

Section on the St. Francis.—A section studied in township 6 N., 4 E., section 29, southeast quarter of the northwest quarter, at a point where the St. Francis River flows directly against the ridge and makes a sharp turn to the south, shows the sequence of strata from a height of 155 feet above it down to the river level. It connects the Copperas Creek section in Cross county with the section on Crow Creek. For the greater part the section is nearly or quite vertical, and is mainly continuous from the loess top of the ridge, to the Eocene clays at the water's level.

Bluff Section on the St. Francis.

Bed.	Ft.		Total.
1.	60.	Loess, nonfossiliferous and unmodified...............	60
2.	40.	Sands and Orange Sand gravels, with large masses of chert and some red pipe clay....	100
3.	60-70.	Bluish or black stratified Tertiary clays, without fossils other than abundant small pieces of lignite...	165

In this section the variegated sands and gravels of the preceding sections are massed together because they are believed to represent a class of phenomena related in respect both to time and cause. The thickness of the gravel member proper is not more than six or eight feet and it is usually somewhat less. But in this section as in all others in which the gravels occur that member is a variable one being often as much as forty or fifty feet in thickness in pockets. The maximum thickness noticed here was but little if any more than ten feet.

Conglomerate.—In the section given above the gravel is sometimes conglomerated, a feature which is noticeable through-

out the ridge when the gravels are underlain directly by the clays or by any other impervious layer. The cementing material here, as in most places, is iron sesquioxide. At the base of the section and near the margin of the stream there are masses of conglomerate that would weigh fully six or seven tons, the phenomenon being more marked in this locality than in any other in the ridge. These masses were traced to their origin in its face and were found about its middle and just above the clay members of the Tertiary beds.

The loess.—The top of the ridge throughout St. Francis county is composed of heavy deposits of loess which present all the features of that formation. In rare cases are deposits containing fossils to be found, and they are all, without exception, below the crest. Usually they are on its flank and do not reach to within at least fifty or sixty feet of the highest points. Perhaps the most marked feature of the top of the ridge throughout St. Francis county is the manner in which it is eroded; it is so rough that but few localities may be tilled to advantage. The whole top is much broken with ravines and lesser ridges which depart from points in every possible direction, presenting what is called quaquaversal erosion.

SECTIONS IN CROSS COUNTY.

The Wynne section.—The following is a section at Wynne in Cross county, in a cutting on the line of the Bald Knob branch of the St. Louis, Iron Mountain and Southern Railway in 7 N., 3 E., southwest quarter of the southwest quarter of section 14, and the southeast quarter of the southeast quarter of section 15.

The Wynne Section.

See Plate II., Figure 6.

Bed.	Ft.		Total.
1.	2.	Thin, silicious, light colored humus, with occasional pebbles..	2
2.	20.	Yellowish, compact, indurated, sandy marl, weathering purplish. The sand becomes more abundant near the bottom. It also contains through-	

out a few pebbles, which become more abundant at the middle and increase in quantity until the following member is reached. This marl breaks off in huge blocks, and, in place, is much fissured. There are no well defined bedding planes.............. 22

3. 2. Irregularly disposed and rudely stratified gravel bed, with pockets of coarse white sand. This stratum thickens to five feet in places. The gravel is mainly yellowish chert, with rather numerous pebbles of purplish quartzite, all being much waterworn and well rounded. Occasionally gravel pockets occur in which the quartzite pebbles are very abundant. These pebbles and such as are derived from a point higher up the wash fill its bottom and are spread out on the surface of the land below as an alluvial fan.. ... 24

4. 6. Irregularly stratified bed of fine clayey sand, party-colored, with white and red tints predominating. At the head of the wash this sand is in place, but below it is evidently a portion of a land-slide. It is usually the party-colored, clayey sand of the Orange Sand division of the Tertiary. The upper three feet are very red and very hard, but contain no gravels. Between it and the preceding member is a two inch layer of coarse sand or fine gravel, which, however, is to be regarded as the base of the former member... 30

Soils of erosion.—The lowest member of this series is readily eroded by the water in the ravine, compelling the fall of the gravel bed. This leaves the clays above as overhanging ledges and allows the estimation of the entire thickness of the beds at this place. It is also seen to be a modification of the loess soil of the main mass of the ridge mingled with the abundant chert carried down from the gravel layer higher up, where it is seen

in place. The section is chiefly useful as indicating the nature of soil that results from the erosion of the mass of the ridge, and illustrates well the changes in the character of a soil when erosion in two or more dissimilar members proceeds unequally or alternately. Careful examination of the gullies and cuts made by the streams which flow to the west about Wynne, failed to show more than an occasional pebble, and often none was seen even in the deepest channels. This seems to indicate that the more easily eroded and finer clay of the loess and similar strata is carried far out on the slope and constitute the chief source of the surface soil of that vicinity.

Evidence of land-slides.—From the sequence of the strata further up the cut it is probable that the section given represents the cross-section of a considerable land-slide through which the stream is cutting. A greater thickness of the gravel bed is exposed an eighth of a mile further into the cut. The bed is here generally quite horizontal, though it is not underlain directly by the clayey sands, but by number two of the preceding section. At this point, also, the gravels are cemented into a bed of conglomerate by a manganiferous iron oxide which aids in staining the underlying and accompanying sands. The whole section at the west end of the cut is a transverse section of a spur of Crowley's Ridge. While the clays resemble those found near the top of the cut, which, however, contain no gravels, it would appear that they are a modified representative thereof rather than their equivalent. The gravels were derived from the underlying Orange Sands and were evidently intermixed during their redeposition. Similar sections are to be seen all along both bases of the ridge from Helena to north of Harrisburg, though once in a while the sequence will be almost entirely reversed, a condition which apparently finds its explanation in former land-slides and undermined bluffs.

Sandstone cobbles.—The gravels of this cutting furnished one large example and numerous smaller ones of a fine siliceous sandstone, very hard, usually well waterworn, though occasionally somewhat subangular. These fragments become a constant though rare feature of the gravels as the northern limit of Poin-

sett county is reached, beyond which they apparently form a normal and abundant constituent. The masses increase in size from Cross county northwards. Though not seen in Phillips county, because not specially looked for, they probably occur in the gravels as far south as Helena. All the gravels of Lee county contain occasional specimens of this sandstone.

The railway section east of Wynne.—At the highest point of the railway cut, some distance further to the east the following section is exposed:

Section East of Wynne.

See Plate II., Figure 5.

Bed.	Ft.		Total.
1.	2.	Light colored and sandy humus	2
2.	20.	Yellowish, indurated loess, much fissured, weathering purplish	22
3.	11.	Brick red or lighter colored loess, tough and less red below. Contains abundant limonite	33
4.	12.	Light drab, siliceous loess clay, weathering into vertical cliffs, becoming indurated on exposure. Both this and the preceding are regularly stratified	45

Phenomena of coloration.—The separation of the four members of the above section is made solely on a color basis and does not necessarily represent strata that are genetically different. But this great change in the coloration of zones of loess is very marked in all the sections seen in the lower part of Crowley's Ridge and a typical one, like this, will serve to explain them all.

The whole series of strata, as here limited, represents different color phases of the same thing, but it remains to ascertain the cause of the great variety of coloration. Careful study of the top and bottom members shows that the bottom layers are somewhat more clayey than are those at the top. They are, therefore, less easily penetrated by water. In addition, the oxidizing powers of the humic and allied acids derived from the vegetation of the topmost member is practically expended on the upper

portions of the loess layer, here some twenty feet in thickness, and their bleaching powers are not noticeable in connection with member number four. But that member is more clayey and acts as a check to the downward passage of waters, and they are retained, largely in the bottom parts of number three. Here, then, the conditions are favorable to the formation of limonite and here that mineral is found. All the apparent differences in these members, then, are acquired, and represent purely chemical processes. The section at the highest point of the cut, therefore, shows only typical loess however different the various layers may be in color.

CHAPTER VIII.

GEOLOGIC SECTIONS SOUTH OF CRAIGHEAD COUNTY—*Continued*.

Geologic sections at Wittsburg.—The most interesting geologic sections and at the same time the most difficult of interpretation are those at and about the village of Wittsburg, on the St. Francis, and on the east face of the ridge. This place is on Spanish Grant 239, in 7 N., 3 E., at a point where the St. Francis River comes very close to the base of the ridge. The wellings of the town are situated, for the most part, on a plateau, closely resembling a terrace, composed of Tertiary clays which have resisted the erosive action of the ancient stream. This plateau rises about thirty-five feet above the level of low water in the river, and is covered with a thin layer of pebbles derived from the Orange Sand deposits which occur in great abundance in the adjoining hills.

A short distance below the village, Rice Branch, a small stream, which is dry most of the year, flows away from the hills toward the east, and furnishes in its cuts opportunities to study the strata which constitute the mass of the ridge for two miles within its eastern margin. In common with most of the eastward flowing streams the head of Rice Branch is an extensive amphitheatre to which, from every side, lead many gullies and great ravines, making a maze of spurs, points, and valleys. Two very characteristic sections are shown on the south bank of the

stream, which, added to the strata exhibited at the town, give a total section of 170 feet in vertical distance The first section is about two and a quarter miles within the ridge near the south limit of the Spanish Grant, and is as follows:

Rice Branch Section, No. 1.

Bed.	Ft.		Total.
1.	30.	Loess, weathering in vertical cliffs, with abundant concretions near the bottom........................	30
2.	10.	Reddish, loess like clay, with abundant coarse sand. The lower portion is obscured by a talus formed of the preceding member. Ten feet only are clearly exposed..	40
3.	15.	Upper portion somewhat obscured; at the middle a fine, highly colored sand. brick red predominating; in some places it is almost a clay.........	55
4.	25.	Orange Sand pebbles mostly of yellowish chert with some purple and pure white quartz and some sand..	80
5.	50.	Drab, light blue, and black stratified clays, the strata being often thin and separated by fine white sand in layers with minute mica plates or particles; numerous large pieces of lignite and small fragments occur scattered throughout this clay. Several thin layers of fine sand in thickness from ¼ inch to one inch and these often thicken locally to one foot. These sands continue to the bed of the river and constitute the chief portion of the Tertiary members of this section..	130

To this section must be added the height of the plateau on which Wittsburg is located which gives a total thickness of about eighty feet for these clays.

Silicified wood.—The bed of Rice Branch is filled with Orange Sands and gravels derived from the adjacent hills, and these show all the features of that member. Among the gravels, in places along the bed of the stream one and a half miles

within the margin of the ridge, was found a large mass of silicified wood * which constituted the greater part of the stump of a very large tree. The mass would weigh four or five tons, though it represents but a small portion of the complete trunk. This tree is a portion of a new Tertiary conifer which has been studied by Professor F. H. Knowlton, of the United States Geological Survey and named by him *Cupressinoxylon arkansanum.* This and the following species will be more fully mentioned in another portion of this report. The same bed furnished another species of fossil tree, but dicotyledonous in its affinities. This species is also new and has been named by Professor Knowlton *Laurinoxylon branneri.* These forms may furnish a basis for paleontologic differentiation of the puzzling members of the so-called Orange Sands of this state. It is worthy of mention in this connection that neither silicified wood nor lignite has been found in place above the Tertiary gravel bed. The silicified wood occurs in the lower portion of the pebble bed and occasionally in the underlying sands. The lignites occur only in the underlying Tertiary clays.

Among the gravels are numerous pieces of fine, very hard, white sandstone, most of which are small, but one was seen which would weigh fifty or sixty pounds. These are commonly much waterworn or rounded and bear the usual evidences of traveled rocks. Numerous large subangular fragments of chert, some of which would weigh thirty or forty pounds, are common and all are much waterworn. One which was broken contained many fossils, principally cross-sections of crinoid stems. Near by was found a fragment of a Carboniferous coral, representing the genus *Lithostrotion.* The only specimen of rock foreign to Arkansas that was observed in the gravels here was a mass of mica schist weighing five or six pounds. It is hardly necessary to add that not a single glaciated pebble has been found either at this point or at any other in Crowley's Ridge.†

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* See chapter XXVI of this report where this example is fully described; also chapter XVI where the silicified woods are treated of as a whole.

† See the end of chapter XIV on crystalline rocks from the Cache River.

The second section on this creek shows substantially the same facts as those given, but it has some local differences and is here introduced to illustrate the local variations of the Pleistocene members of the ridge. This section is nearly a mile east of the first.

Rice Branch Section, No. 2.

Bed.	Ft.		Total.
1.	1.	Light colored, sandy humus, supporting a scanty vegetation	1
2.	4.	Coarse and fine sands, reddish in color, interstratified with occasional pebbles; irregularly disposed, thin bands of small nodules of red ochre	5
3.	28.	Stratified and cross-bedded red sands, very fine, graduating into reddish or even white sands below. From a point about eight feet down in this member bands from four inches to eighteen inches in thickness of small gravels are cross-bedded with the white and yellow sands	33
4.	3.	Coarse, rudely stratified, coarse Orange Sand and chert with some fine sand	36
5.	3.	Yellowish and whitish sands, with very few pebbles. These rest immediately on the same clays as are found in the preceding section and which are continuous to the bed of the creek	39

Mineral waters.—A characteristic feature of the waters from these clay strata is well illustrated near the mouth of Rice Branch. A drift was made into the hill on the west face of the bluff and after a few days several gallons of water had collected in a low place in the floor. This was found to be strongly impregnated with alum, and to contain a little iron. It is valueless from a commercial standpoint, but it enjoys a local reputation. Nearly all the spring waters which flow from the clays have more or less alum in them, while occasionally one is strongly saturated with hydric sulphide. This seems to be derived from the decomposition of iron pyrites which occurs sometimes in considerable quantity in certain portions of these

Tertiary clays. The Tertiary clays of this particular locality contain abundant and large crystals of selenite (gypsum).

Land-slides.—There are numerous good illustrations of ancient land-slides about the village of Wittsburg. While interesting in themselves only as showing the great amount of erosion which certain of the lower strata suffered before it was possible for the higher portions to slide or fall, they yet give additional interest to the region in disclosing cross-sections which would otherwise not be revealed. They also complicate the stratification of the lower portions of most natural sections and render them difficult of interpretation. One can by no means be sure that the particular stratification he sees is strictly normal.

Section west of Wittsburg.—There is a very useful section of this character, however, in the road leading over the hill in the west edge of the village. The loess, which in this vicinity is from sixty to eighty feet in thickness, has been eroded away and a kind of plateau of gravels and sands constitute the upper portion of the section. A deeply eroded gulley has cut far down into the sands and discloses a cross-section of a spur of the ridge representing the product of pre-loessial erosion. This section is given in Plate VII, Figure 1., and seems to show that the loess and related deposits are here, as in many similar localities, deposited upon a rearranged Orange Sand. Moreover, the pebble bed has been comparatively recently transported and redisposed over fringing deposits of newer loess silt, as at B. The line Z represents the outline of the spur on which the loess was originally deposited. The surface soil is loess with abundant chert pebbles and not a little sand, the pebbles being especially abundant at the surface. The points K and D are where typical and unmodified loess occurs, neither of which places has any pebbles and represent undisturbed deposits of that member. At Y are from ten to fifteen feet of Orange Sands, with some fine gravels arranged in zones or lines, the sands themselves being the usual cross-bedded and party-colored ones of the region. At A is a humus with abundant pebbles and much sand, the whole being derived from the same subjacent strata. A layer of very fine

drab pipe clay, G, much jointed, extends entirely across the adjacent hill and ends abruptly against E, in the southwest, which is a typical and undisturbed pebble bed with some sand, and abuts directly against typical loess, K, on the northeast. At C is also a pebble bed with some sand and much yellow clay, both of which have evidently been rearranged. At R, there is a heavy bed of red, white and yellow sands, the exact equivalent of Y in the upper part of the middle section. From the relation of G to K and to E, the similarity or identity of Y and R, the fact that in the main section C and E are much higher up in the hill, it would appear that the mass of pebbles indicated by C represents a huge block of Orange Sand gravel which has slid down the slope of an old surface of erosion. While G is horizontal and undisturbed it has a representative or equivalent at T which is a jointed and inclined layer of red pipe clay or ochre. Differing only in color it may be the old portion of G oxidized. At H are heavy beds, some twenty feet in thickness, of pure white sand with no pebbles, cross-bedded and stratified. The whole exhibits a vertical section of about forty feet. It is possible to multiply and get a hundred such sections within a few miles of Wittsburg, and, indeed, at nearly every locality where the present bed of the St Francis is close to the base of the ridge.

Remarks on the above section.—The general section of the ridge at Wittsburg closely agrees with that at the Big Bluff in St. Francis county, and with the Copperas Creek section which is given on page 70 of this volume. There are, however, minor but important features in this section which are not found in that of St. Francis county, but which characterize most of the sections from this point to the north boundary of Poinsett county. It is especially marked in the Copperas Creek section and here at Wittsburg. In the road, on both sides of the cutting, are two highly inclined strata of siliceous iron ore, of varying thickness. This member often appears as a series of segregations, more or less closely connected, while at other places it forms considerable beds, sometimes two or more feet in thickness. It is always both overlain and

underlain by beds of regularly and usually horizontally stratified Tertiary clays, drab or bluish in color, and it is well below their top. This is their relation at Wittsburg, at Copperas Creek, and near Harrisburg.

The section made at the village of Wittsburg is built up of a series of observations made at points near each other, but does not represent a vertical sequence actually seen at any single locality. The various vertical points were determined from barometric readings referred to the plateau elevation of the town. The section is as follows:

Composite Section at Wittsburg.

Bed.	Ft.		Total.
1.	60.	Loess, yellowish in color, redder below, abounding in solid calcareous concretions which are often of large size and irregular shape. These concretions are mainly confined to the lower portion of the middle layer. At the extreme bottom of the loess numerous chert pebbles occur...........	60
2.	8.	Party-colored, cross-bedded, clayey sands, red and white predominating. At various points are irregular bands of deep red pipe clay which usually extend for a short distance only. Occasionally these become pockety and thicken to three or four feet. This member often contains enough clay to cause induration......	68
3.	5.	Gravel bed, with coarse sand, usually red. This layer varies from two to twenty feet in thickness in the several localities about the village. It is commonly from three to six feet in thickness.....	73
4.	8.	Light drab or blue, horizontally stratified clays, with numerous laminæ or partings of fine white or yellow sand. The upper surface is very undulating and is probably an old surface of erosion	81
5.	1.	Seggregations of iron ore, dipping west at an angle of about 5°. This dip is exactly the op-	

		posite of the slope of the hill	82
6.	12.	Clays similar in all respects to no. 4	94
7.	1.	Iron ore the same as bed no. 5 except that it is somewhat thicker. These two members have been traced from Copperas Bluff to a point near the St. Francis county line. The ore thickens to two feet in many places, though it is sometimes represented only by thin, flat nodules for long distances	95
8.	65.	Horizontally stratified clays with thin partings of fine white sand containing mica scales, to the bed of the St. Francis. These clays resist erosion and constitute the main mass of the village plateau. They are Tertiary and often contain small fragments of lignite	160

The clay members of the bottom of this section, nos. 4 to 8, are all of the same age, and are to be considered as a single member of the vertical section. They are rendered practically tripartite by the two layers of siliceous iron ore and are here separated on that basis alone. In none of the clay beds of the sections about Wittsburg were fossils found, except the lignite fragments, and these are of no value in determining questions of age.

Loess fossils absent.—A noticeable feature of the loess deposits about Wittsburg is the entire absence of fossils and the unusual abundance of calcareous nodules. A few observers have recorded the finding of pebbles or of organic neuclei in many of these peculiar bodies about which segregation is assumed to have begun. The writer has crushed many hundreds of these nodules in the loess of the upper Mississippi valley, but found few or none with such neuclei. During the study of loess at Wittsburg hundreds of these concretions were broken, but always with negative results. The only difference which is characteristic lies in their solidity. I do not think that the beginning of their formation can be explained on any other than chemical grounds.

Relations of gravel bed and clays.– In two or three places

in the vicinity of Wittsburg the pebble bed rests directly on the Tertiary clays; that is, they are without the usual beds of sand so commonly interpolated. At all such places the pebbles are cemented by iron oxide into a conglomerate of varying thickness. This feature becomes a common one farther to the north, though the pebbles there occupy the highest hilltops.

Redisposition of gravels.—Another feature in the occurrence of the transported pebbles is to be observed along the east face of the ridge from a point north of Le Vesque to Helena, a distance of some fifty miles, where they form a fringing zone for nearly the whole distance. This pebble zone is derived, of course, from the Orange Sand pebbles in place near the top of the hills, but having been washed down from above they constitute a natural gravel road all the way to the end of the ridge. The pebble zone varies in width from a few yards to three quarters of a mile, and is rarely absent entirely for any considerable distance. In the bed of the St. Francis at and below Wittsburg are immense bars of these gravels some of them being nearly or quite half a mile in length. They constitute a particularly noticeable feature in a river whose channel is eroded in a bed of alluvial clays, naturally devoid of rock or pebble, and they often determine the course the river must take. These bars are sometimes twenty-five feet or more in height and their materials are all derived from the adjacent hills.

CHAPTER IX.

GEOLOGIC SECTIONS SOUTH OF CRAIGHEAD COUNTY—*Continued.*

Section on Copperas Creek.—Two or two and a half miles north of Wittsburg Copperas Creek flows eastward from the ridge, and after a sinuous course through the alluvium of the St. Francis bottoms, joins the St. Francis River some distance to the south. Where it leaves the hills this stream has cut away the greater part of a north and south spur and exposed its stratigraphy. The section was observed some thirty years ago by Professor E. T. Cox and reported by him.* The sequence at the present time is as follows:

* Second Report of a Geological Reconnoissance of Arkansas, pp. 418-419.

Section at Copperas Bluff, Cross County.

See Plate VII., Figure 2.

Bed.	Ft.		Total.
1.	2.	Light yellow and siliceous humus.	2
2.	45.	Loess, with abundant concretions at the middle, pebbles below, and especially abundant near the bottom of the layer. Weathers into vertical cliffs. At the upper limit of the pebbles in this member the color begins to get red; it is deeper below......................	47
3.	5.	Pebble bed, mainly of yellowish chert, with much party-colored sands. The gravels are not as coarse as usual, and the bed contains sandstone pebbles from three to four inches in diameter; the chert pebbles are smaller. This bed is quite thin at the extreme end to the east of the section, being there but a foot in thickness, but near the west end of the cutting it becomes eight feet thick	52
4.	5.	Reddish and indurated, cross-bedded, rather coarse sands, with abundant small pieces of light yellow ochre disseminated in patches...	57
5.	15.	Drab to purplish sandy clays, horizontally stratified, with abundant fragments of lignite......	72
6.	1.	Ironstone nodules, distributed somewhat regularly in a narrow zone, but for the most part horizontally. The layers of the nodules may be easily peeled off when exposed for a time to the weather. Some of the nodules are hollow or filled with sand.........................	73
7.	10.	Bluish stratified clays, with abundant organic matter, some as lignite fragments, and very numerous gypsum crystals...............	83
8.	1.	Ironstone concretions, differing from the first concretionary layer in structure and in abund-	

ance. This member forms a marked ledge and sags near the west-end of the cut......... 84

9. 10. White and yellowish fine stratified sands which thin out and disappear towards the west...... 94

10. 12. Sandy, stratified, bluish clay, with organic matter and abundant large fragments of lignite. This member contains immense quantities of selenite, and many acicular crystals radiating from a common center. It is much darker in color than any of the overlying clays.. 106

Pyrites and iron nodules.—Iron pyrites were not observed in this section although, according to Cox, they occur in abundance. There are, however, abundant scales of mica in the sands which are interstratified with the clays near the bottom of the section. This feature is most marked at a second cutting, made by the stream, on the right bank a mile and a half farther into the ridge. At this place which shows a section seventy-five feet in length and from thirty-five to forty feet high, the ironstone stratum exists as three distinct layers, each about one foot in thickness, and extending throughout the whole length of the section. They are, as at Copperas Bluff, nodular or concretionary in character, and occur also in the Tertiary clays. They are often a foot in diameter, though commonly much smaller. The strata containing these concretions are horizontal, or nearly so, and aggregate about eighteen feet in thickness. The clays contain much sand at this locality and in this sand is abundant mica in minute scales. There are also abundant selenite crystals, an inch or more in diameter, and numerous fragments of lignite.

Leaching of the clays.—It is noticeable here, and indeed at nearly all other places where lignite is found in detached masses or in layers in these Tertiary clays, that the immediately contiguous clays are bleached to a much lighter color; a phenomenon purely chemical in character and beautifully illustrative of the deoxidizing powers of organic matter. This will serve to make intelligible the fact that all the considerable deposits or

beds of lignite in Crowley's Ridge are underlain by a light drab colored clay.

Origin of the iron and gypsum.—The abundant selenite crystals in the argillaceous members of this section are produced by the decomposition of the iron sulphide (iron pyrites) and the action of the product (copperas) on the carbonate of lime dispersed through the clays. After a somewhat complex series of reactions there results sulphate of lime and carbonate of iron. The sulphate of lime is the selenite, much of which separates out as crystals; the iron may remain as a bed of carbonate, may be further changed so as to become a peroxide, or may, since it is soluble, be entirely removed. It would seem from the constant association of these two minerals, the gypsum and the iron, in these beds throughout the ridge that some similar history is illustrated by their occurrence. In the absence of fossils in these strata it is possible that such relationships as this may prove of taxonomic value.

Prairies.—There are several small areas of prairie land in Cross county, evidently at one time a single larger prairie which was possibly continuous with that of St. Francis county on the west. These areas are located as follows: 9 N., 3 E., in sections 32 and 33; 8 N., 3 E., sections 19, 20, 29, 30, and 31; 7 N., 2 E., sections 2, 3, 11, and 10; 8 N., 2 E., sections 3, 16, and 17. Nearly every square mile of the surface west of the ridge in Cross county drains into the sluggish L'Anguille, and, as the general slope is but a few inches to the mile, the whole of that area is imperfectly drained. The prairie regions are little or no better than the wooded portions in this respect and both rest upon a wet clayey hard-pan that often forms a great part of the surface soil. Away from the ridge to the west at a distance of a mile one reaches the limit of the best arable land in Cross county. Beyond this stretch are the wet limonitic "buckshot clays," which render the results of agriculture more or less uncertain. The prairie lands seem to be unpromising for tillage, but are very valuable for stock raising. They

produce several varieties of native grasses in abundance and might be made still more productive than they now are.

These small prairies are surrounded with a dense growth of the forest trees common to the region among which are many white and willow oaks, black gum and sweet gum of great size. The willow oaks are especially abundant and are characteristic of the poorer soils; they thrive on these wet clayey lowlands.

Sections near Vanndale.—At Vanndale, the present county seat of Cross county, the ridge is very much lower than at any other point on the west, consisting of many rolling spurs of low elevation. Few opportunities are therefore presented for determining the stratigraphy of this part of the county. In several rather deep ravines near the town are the sands with a few pebbles, that usually overlie the gravel bed, while loess is the characteristic surface member. In following up the longer ravines one usually comes upon the pebble bed of the Orange Sands outcropping at varying elevations and in differing thicknesses, indicating that its peculiarly erratic, vertical distribution might reappear here were the conditions for observation favorable. On the Wynne-Vanndale road, nearly a mile south of Vanndale, in 8 N., 3 E., section 27, a section is exposed which illustrates the structure of this spur of the ridge. It is as follows:

Section One Mile South of Vanndale.

Bed.	Ft.		Total.
1.	2.	Light colored and sandy humus....................	2
2.	8.	Loess, without concretions, pebbles in lower portion, becoming more numerous downwards; reddish below or darkening to a chocolate color..	10
3.	7.	Pebble bed, with abundant party-colored sands, the thickness varying from four to eight feet.	17
4.	4.	Party-colored fine sands, with considerable clay.	21

Notes on the section.—This is the section as seen in a deeply eroded gulley at the roadside. The locality is about

thirty feet above the level of the lowlands to the west. The pebble bed is neither of uniform thickness throughout this gulley nor is it horizontally arranged. A few very large masses of white siliceous sandstone occur, but most of the material is of the ordinary cherty sort. The clayey sands at the base of the section are more or less impervious so that water collects in the pockets of that bed. In such places the pebbles are cemented into a conglomerate, and this is sometimes found in large flat masses in the bottom of the excavation. The pebble bed is inclined to the east at a small angle, while the hill slopes to the west.

Tertiary.—The only outcrop of Tertiary rocks near Vanndale is in 8 N., 3 E., section 27. In the botton of a stream in this locality there are exposed about thirty feet of bluish Tertiary clays, with sandy partings, abundant mica scales, and occasional lignite particles. The tops of the hills around are covered with loess, immediately below which are the pebble beds of the region. These in turn lie directly upon the Tertiary clays, are apparently undisturbed, present all the usual features, and are therefore somewhat abnormal in being thus directly underlain by the clays. The latter are horizontally stratified, and present no unusual features.

Cherry Valley section.—At Cherry Valley, near the northern boundary of Cross county, occurs a very instructive section, the best that is to be seen on the west of the ridge south of Harrisburg. This section is in 9 N., 3 E., the northeast quarter of the northwest quarter of section 23, and is about one mile southeast of the railway station at Cherry Valley.

Section One Mile Southeast of Cherry Valley.

See Plate VII., Figure 3.

Bed.	Ft.		Total.
1.	3.	Light reddish, somewhat siliceous humus, supporting an abundant vegetation........................	3
2.	5.	Gravel bed, intermixed with sands and clays, irregularly stratified, differing in thickness at various points but with a maximum of about	

six feet. The pebbles are chert, deeply stained with iron and are often cemented near the base into a conglomerate.................................... 8

3. 10. False-bedded, party-colored fine sands, reddest at the top, becoming yellow and finally white below. 18

4. 7. Dark brown to black clays, horizontally stratified, with laminæ separated by partings of fine white sand. Below the layer becomes very black and has an abundance of organic matter. It varies in thickness, increasing from two feet at the north to ten feet at the south end of the exposure. It ends below in a thin layer of iron ore that makes a clear line of separation from the following member................................ 25

5. 14. Fine, sharp, white sands, regularly stratified, with numerous small patches of yellow ochre scattered throughout. This stratum is easily eroded and leaves the overlying one projecting from the face of the hill.. 39

6. 8. Dark brown to black clays, laminated, with fine white sand as partings, which sand contains abundant scales of muscovite. Fossil leaves of deciduous plants and fragments of lignite are abundant. The laminæ of the stratum are everywhere horizontal. The bed is ten feet in thickness in one place................................. 47

7. 3. Drab colored, jointed, stratified clay, dipping to the east at an angle of 3° to 4°. In it is a layer of concretionary, siliceous iron ore, which is arranged regularly and is independent of the dip of the stratum containing it.......................... 50

Old surface of erosion.—This is a particularly interesting section, since it does not show the prevailing loess deposits at its top but does clearly show a surface of former erosion, represented in the plate by the line X—Y. This is further illustrated at Z, where a large mass of clay derived from number 4 of the general section is seen to be imbedded, at a much lower point,

in a sandy soil containing many pebbles likewise derived from above. The soil is a modification of all the upper members of the section. At Q there is an older gulley, eroded well down into the iron-bearing zone of clay, but now well nigh filled with pebbles and sands from above. The stream at this point is, therefore, now flowing at right angles to an ancient though small channel.

Bleached pebbles.—In the Cherry Valley section is well illustrated one of the chemical problems frequently presented in the ridge. These rearranged gravels are always well bleached and are always distributed without regularity. This bleaching is often helpful in aiding one to decide whether or not the pebbles are in place, and it thus becomes useful at numerous points on the slope of the ridge. Except under unusual conditions, as when those beds form the surface deposits of the higher hills in the forests, they are never bleached. But whenever they are so situated that organic matter can reach them they are well bleached. In such rearrangement these conditions are fulfilled and the organic matter of the soils with which they are covered entirely removes the iron which usually coats them.

Absence of loess.—While there are no deposits of loess in this particular locality, that formation occurs in great beds higher up in the hills, capping them and presenting all its characteristic features. At some points it descends to a lower level, as on Cooper's Creek, about a half mile north of the above section, where a twenty foot section of a low foot-hill shows eight or ten feet of loess resting directly upon Orange Sand pebbles. Beneath the pebbles are the customary party-colored sands, and under these the Teritiary clays. At this place the clays are drab in color and contain an abundance of leaves of deciduous trees with an occasional piece of lignite. In this section, too, the pebble bed is cemented into a conglomerate, great masses of which, tons in weight, lie in the bottom of the bed of the stream. The iron ore bed is also present. It will be noted, therefore, that the sections are practically identical and the absence of loess in the first is doubtless due to greater erosion at that locality.

CHAPTER X.

GEOLOGIC SECTIONS SOUTH OF CRAIGHEAD COUNTY—*Continued.*

Geologic Sections in Poinsett County.

Topographic features.—In Poinsett county Crowley's Ridge has a maximum width of about three miles and a minimum of a little less than one mile at the northern boundary of the county, while the average width is not more than two and a half miles. From the general character of the materials composing the ridge and the ease with which they yield to eroding agencies it will readily be inferred that throughout the very narrow portion the ridge is very irregular in height and direction and the lateral gullies are numerous and short with precipitous sides. The Poinsett county portion of the ridge is somewhat lower than the average height of that portion south of Harrisburg, a condition due to the erosion on the opposite sides of a very narrow watershed from which streams may flow to the one side or to the other. Many of these gullies draining in opposite directions have common heads, and at such places the ridge is much lower.

The loess wanting on hilltops.—At many places in Poinsett county the loess which caps the hills to the south is wholly wanting at the top, and often occurs only along their slopes, while in many places it does not occur at all. Whether this is due to its having been removed by erosion or whether it has never been deposited on the hilltops I am unable to decide.

Pebble beds.—The higher hills about Harrisburg are capped with heavy deposits of the pebbles, and this feature is a marked one at all the points of greatest elevation throughout Poinsett county. These deposits of pebbles appear to be much heavier here than they are to the south. The individual pebbles are also somewhat coarser and there are numerous large masses of chert and of white sandstone at nearly every considerable exposure, especially in the bottoms of the numerous small streams on both the eastern and western slopes of the ridge. Silicified wood is here more abundant than at any place farther south. Near the he village of Harrisburg, indeed all about it, the gravels form

the chief feature of the surface of the hills and of the roads. As usual they are frequently cemented into large masses of conglomerate. This is well illustrated in 11 N., 4 E., the northwest quarter of the southeast quarter of section 19, in a small ravine in which the gravels outcrop abundantly, and where the sands are cemented by iron oxide into large masses of conglomerate. Immediately below the gravels in this immediate locality is a layer of light bluish Tertiary clay from one foot to eighteen inches in thickness. Beneath this clay is a ten inch layer of brown lignite alternating with thin layers of impure clay, while below the clay is a stratified bed of whitish drab clay which is exposed to a depth of about three feet.

This is the only locality in Crowley's Ridge where the lignite beds rise to such a height, or where the stratigrapic relations of the lignites and Orange Sands are so intimate. The beds were traced three hundred feet to where they disappear under the crown of the hill, which is here about twenty feet higher than the gravels. The greater portion of the road leading south, as far as England Creek two miles away, and all the road to the north, to near the county line, is upon these gravels.

Spencer Creek section.—An instructive geologic section occurs on Spencer Creek, one mile north of Harrisburg. This creek flows with a sinuous course from near the heart of the ridge through a deep, wide trough of its own making. It is one of the few streams in Poinsett county whose valley is wide enough for cultivation, and there are two or three farms along its course, chiefly in the lower portion. As a usual thing it is dry or nearly so during the greater part of the summer.

Section on Spencer Creek.

Bed.	Ft.		Total.
1.	1.	Humus, with considerable sand and a few scattered pebbles	1
2.	20.	Yellowish, loess-like marl, indurated below, weathering into vertical cliffs. This layer becomes much redder below, has occasional seams of pebbles with considerable red sand among the peb-	

bles. At the very bottom the clay is almost entirely replaced by a coarse, brick red sand...... 21

3. 13. Horizontally stratified white sands, alternating with light slate colored layers of plastic clay, the thickness of the clay varying from half an inch to five inches. The thicker layers of clay are laminated, the laminæ being separated by thin layers of a very fine white sand, though these finer sand partings are sometimes stained yellow by iron oxide. Below the first five feet these clay bands almost entirely disappear and the whole becomes a very fine white horizontally stratified sand. This member is remarkable for the regularity and horizontality of its stratification.. 34

4. 23. Stratified, bluish to drab clays, with abundant small fragments of lignite scattered throughout, though these particles are often arranged in zones from two to three inches in thickness. Near the bottom is a heavy deposit of siliceous iron ore, often forming the floor of the creek and at other times jutting out as a ledge from the bank. The thickness of this iron clay-stone varies from one foot to fifteen or twenty inches....... 57

Farther down the creek and west of the road is a continuation of the above section which extends its general features nearly half a mile to the west. In this exposure the iron claystone is nodulous and is represented by very large segregations instead of by a bed. Lignite is much more abundant and the fragments are larger than at the first mentioned locality, but they are arranged in an undulating zone throughout the whole section. At the top of the section, for seven feet of the total thickness, which is twenty-five feet, the character of the soil clearly resembles the loess clays and, though it is somewhat more deeply colored and more clayey than usual, it probably represents that deposit. In the creek bottom are large quantities of chert pebbles derived from the Orange Sands, and among them

many fragments of silicified wood and numerous masses of chert, some of which weigh two hundred pounds or more. One of these when broken open disclosed abundant casts of crinoid stems.

The Bolivar Creek section.—By far the best section exhibited in Poinsett county is on Bolivar Creek, three and a half miles north of Harrisburg, on the west side of the ridge. Bolivar Creek is the largest stream in this part of the county, and constitutes the main tributary to, or is rather the chief source of the L'Anguille River. The exposure faces north and is continuous for about four hundred feet. The relations given in the section, however, are made out from observations extending over a mile, and represent a vertical distance of more than one hundred feet. The point at which the lignite bed is exposed is only about thirty feet in height, but it underlies a vertical cliff at that place.

Section on Bolivar Creek,

(11 N., 4 E., N. W. ¼ of the S. W. ¼ of section 8.)

Bed.	Ft.		Total.
1.	2.	Humus, with much sand and some very tough and purplish red clay	2
2.	40.	Party-colored, cross-stratified sands, with pebbles abundantly scattered throughout the lower fourth, passing gradually into a heavy bed of gravels with much sand below. This is a characteristic Orange Sand deposit	42
3.	60.	Horizontally stratified sands, white and light drab predominating, with considerable clay, especially below; these sandy clays at the bottom present occasional patches of potters' clay, usually drab but sometimes red or yellow	102
4.	15.	Chocolate colored joint clay, containing much organic matter, dark colored below where are abundant scattered fragments of lignite derived from bed no. 7. This clay weathers into small cuboidal blocks often but two or three inches on the face	117

5. 7. Lignite from five and a half to seven feet in thickness. On exposed faces this lignite breaks up into many small cuboidal blocks, and finally crumbles into powder. The bed is sometimes divided by thin seams of drab clay into two or three parts. These division planes, however, are not continuous for long distances. This bed was traced for over 1,500 feet in an east-west direction... 124

6. 3. Light drab, compact, stratified fire-clay, very stiff and tough and occasionally chocolate colored. This clay forms the bed of the creek and its entire thickness is not determinable from natural exposures...... 127

The Lignite.—The lignite bed no. 5 first outcrops in the bed of Bolivar Creek about three hundred feet east of the road, but it soon disappears. A few hundred feet further up the stream it again appears in the creek bottom and in the side of the bank, being exposed for nearly a thousand feet. It next appears in the hill, and forms part of the section given above. A short distance up the stream from this section it again forms the bed of the stream.

The western exposure of this lignite bed is about an eighth of a mile west of the road in an old drift on the south bank o the creek near the level of the water. The abandoned drif made many years ago by some enthusiastic miner, is the only opening at which an attempt has been made to mine this lignite. It has a local reputation for being an excellent fuel, but no one could be found who knew of its value from actual trial. At this western exposure the characters of the material are substantially the same as those presented at the section given above, but it appears to withstand weathering much better at the drift than elsewhere.

Lignitized stumps in place.—In the bed of the stream at the point at which the Bolivar Creek section is made (p. 80) are several perfectly lignitized stumps in place, with roots radiating in every direction, and deeply imbedded in the underlying drab

fire-clays, bed no. 6 of the section. Nine of these stumps are near each other and all are in place just as they grew in the mud of the swamp which now forms the fire-clay at the bottom of the section. The lignitized roots are, in some instances, traced for ten or twelve feet from the mass of the stump, showing that the remains visible are those of large trees. The largest stump has a diameter of a little more than thirty inches. Lying promiscuously about the stumps are many lignitized trunks, limbs, and other fragmentary parts of the trees, all more or less deeply buried in the drab fire-clay.

Gravel beds.—The hills which the road crosses between this Bolivar Creek locality and the town of Harrisburg are all capped with pebbles. There are a few features of these gravels that were not noticed to the same extent heretofore, the most marked of which is the presence of great quantities of pebbles of purple quartzite. Another feature is their greater thickness, occasional beds being found of more than twenty feet in depth. A third character is the abundant and very large masses of chert seen either in the gullies and creeks in place, or scattered about the surface along the road, particularly where they skirt the hills at or below the level of the gravel bed. All these features may be seen in a deep gully on the west side of the road a mile and a half south of Harrisburg. The top soil is a very red clayey representative of the loess, varying in thickness, with pebbles abundantly distributed through its lowermost portion. This is followed below by a very thick bed of pebbles, cemented in places, followed still lower down by heavy beds of party-colored, cross-bedded, sands, with red predominating. These sands are very fine below, and contain considerable patches of clay. It is, as here seen, a fair representative of the Orange Sands in those parts of the ridge which have been subjected to extensive erosion. Almost always, on these lower slopes of the west side of the ridge, the earlier Pleistocene sands and clays are mingled with the gravels, sands and clays of the Tertiary, the whole forming a very peculiar soil, but one of but little value for purposes of geologic differentiation. In short, wherever the ridge has been so deeply eroded as it has been about Harrisburg, the soils are

neither the one nor the other, but a variable mixture of both in which first one then the other of the characteristic rocks of the hills are most abundant.

Other lignite beds.—There is a small bed of lignite on Otter Creek, in 10 N., 4 E., the northeast quarter of the northeast quarter of section 20, but it is not thought to have any connection with the lignite of Bolivar Creek. It is underlain by the characteristic fire-clay, is nowhere more than two feet in thickness, brownish in color and interstratified with drab colored clay. The locality is at the base of a bluff of Tertiary clays which rises about forty feet above the bed of the stream and are in turn surmounted by the ordinary Orange Sand deposits.

Few Tertiary exposures in Poinsett county.—No good sections occur on the east side of the ridge in Poinsett county though the hills are usually steep and high. At no place have more than a few feet of Tertiary clays been found exposed, and these only in the bottoms of the most deeply eroded ravines. The hills on the east side are all capped with gravel and sands, and, as the erosion is similar to that on the west, these gravels often form the surface of the country along a narrow belt.

Soils.—All of the western part of Poinsett county, except a small area in the extreme northwest, is drained by the L'Anguille River. The whole surface slopes to the west at a slight angle, and, being entirely underlain by a hard-pan soil nearly impervious to water, is not especially well adapted to successful farming. There are a few small prairies similar to those of Cross county. Most of the land over this part of the county is limonitic "buckshot" land, though in a few places what is usually the underlying hard-pan forms the surface. Post-oak slashes abound, and the common willow oak of these wet low lands finds every opportunity for great development. The zone of really valuable arable land is rather narrower than it is in the counties to the south, and even in the narrower belt the land does not seem to be so fertile. The analysis of these soils will serve to indicate their needs in respect to possible artificial improvement. The ridge soil was sampled for this purpose at a point nearly an eighth of a mile north of Spencer Creek, on the top of the highest

hill by the road. The object was to get a soil which would probably contain less of the mixed materials so characteristic of the lower derived soils.

CROWLEY'S RIDGE SOIL.

Analysis of a soil from the top of Crowley's Ridge, one eighth of a mile north of Spencer Creek, Poinsett county:

Dried at 110°–115° Centigrade.

Silica, (free and combined)	85.83	per cent.
Alumina	7.50	" "
Iron (ferric) oxide	2.66	" "
Manganese	trace	....
Lime	0.32	" "
Magnesia	0.35	" "
Alkalies, by difference	1.16	" "
Loss on ignition	2.18	" "
Total	100.00	" "
Air-dried sand in air-dried soil	64.80	" "

It will be noted that the soil is deficient in lime.

HARRISBURG SOIL.

The following is an analysis of a soil taken, like the last, from near the top of a gully three quarters of a mile west of Harrisburg, and about the middle of the strip of land which is considered the best of the region for farming purposes.

Specimen dried at 110°–115° Centigrade.

Silica, (free and combined)	81.79	per cent.
Alumina	9.37	" "
Iron (ferric) oxide	4.03	" "
Manganese	trace	....
Lime	0.31	" "
Magnesia	0.38	" "
Alkalies, by difference	0.86	" "
Loss on ignition	3.26	" "
Total	100.00	" "

An air-dried specimen of this soil contains 30.92 per cent.

of sand. This soil is also deficient in lime and has a much smaller percentage of alkalies.

It is fair to state that the soils that are cultivated certainly contain more organic matter than this sample, though they are directly derived from it. The lower part of this soil generally contains great quantities of limonite, in the form of the so-called "buckshot" and is generally very wet. This is because the soil underlying it is very clayey and constitutes the typical hard-pan of the region.

The following is an analysis of a clay from the side and near the bottom of the same gully as that from which the preceding analysis was made:

HARRISBURG CLAY.

Specimen dried at 110°–115° Centigrade.

Silica (free and combined)	81.37	per	cent.
Alumina	8.52	"	"
Iron (ferric) oxide	2.88	"	"
Manganese, red oxide	1.01	"	"
Lime	0.44	"	"
Magnesia	0.50	"	"
Potash } Soda }	2.40	"	"
Loss on ignition	2.88	"	"
	———	"	"
Total	100.00		
Air-dried sand in air-dried clay	28.08	"	"

The noticeable feature of this clay is the high percentage of manganese as compared with the other soils, the second of which is, without doubt, derived from the same sources as this hard-pan sub-soil, that is to say from the adjacent hills. In all the gullies about Harrisburg this clay is a very marked feature, and it is passed through in sinking nearly all the wells put down west of the town. Seen in cross-section in deep gullies, as in the bed of England Creek two miles south of Harrisburg, this hard-pan often contains a great abundance of small limonite nodules very similar to those found in the sub-soil overlying it. In several places along England Creek the nodules are very

abundant and form a zone fifteen inches in thickness about seven feet from the top. The best agricultural soils of the ridge are those in which loess clays largely predominate.

CHAPTER XI.

GEOLOGIC SECTIONS NORTH OF POINSETT COUNTY.

Complete sections wanting.—In the part of Crowley's Ridge lying north of Poinsett county there is not a single vertical section which shows the complete stratigraphy. The general structure can be made out only after combining many incomplete sections, and even then lithological characters must be depended upon in the identification of some of the beds. There are no fossils, save in one locality in Greene county (Hardy's mill), and comparisons and correlations cannot therefore be based upon them. The gravels of the Orange Sands spread over the whole of the western third of this area, often rising to the tops of the highest hills in the eastern half, but, except in few localities, they are wholly wanting in all valleys and on hills of moderate elevation. Though found in sections disclosed in digging or boring wells on the east side they are always bleached, which fact leads one to conclude that they have been rearranged since they were originally deposited.

The loess.—The familiar loess clays of the sections studied in the southern portion of the ridge are absent north of Poinsett county, or if present, form a zone of clay which never rises to the tops of the hills. This is, perhaps, more applicable to the region north of Jonesboro, about which town, in the valleys and surmounting the lower hills, are great deposits of typical loess, without fossils, indurated, tough, and usually not thicker than twenty or thirty feet. In most places there is also an entire absence of concretions. Jonesboro is almost entirely built on this loess clay which is found in well sections in every part of the town.

Brick clays.—The surface soil of Crowley's Ridge north of Poinsett county is derived from these loess clays and contains, in addition, a quantity of sand from the higher adjoining hills. is soil constitutes the greater portion of the arable lands above

the creek bottoms. It is also used in making brick. For brick manufacture a few inches of the top soil is stripped off, care being taken not to go too deeply into the subsoil which is too stiff a clay for such use. The bricks made from this subsoil crack when sundried, and often go to pieces when burned. When tempered with the surface clay however very good rough bricks are made. With improved methods excellent bricks could be produced from this soil.

BRICK CLAY.

Analysis of the brick earth in use at Jonesboro:

Specimen dried at 110°–115° Centigrade.

Silica, (free and combined)	79.49	per	cent.
Alumina	8.71	"	"
Iron (ferric) oxide	3.43	"	"
Lime, magnesia, and alkalies, (by difference)	2.10	"	"
Manganese, red oxide	2.44	"	"
Loss on ignition	3.83	"	"
Total	100.00	"	"
Air-dried sand in air-dried clay	33.40	"	"

The hard burned bricks seen in the kilns are of a peculiar purplish red color, the intensity of which could be made a fair test of their hardness. The soft burned bricks are of a light red color and stand the weather but indifferently.

The soil.—In the valleys, such as the valley of Big Creek, the soil is a stiff, whitish, limonitic clay, tilled with difficulty, wet, cold, lumpy, and not especially productive. Nearly two thirds of the total area of Craighead county consists of soils of this sort. In the immediate vicinity of the ridges, sand and gravel topped as all the higher ones are, the soils contain considerable sand and occasional pebbles. On the east slope of the ridge, as far north as Village Creek in Greene county, the soils are somewhat better, but are confined to a narrow zone upon and along the narrow margin of the ridge.

Bleached gravels.—One and a half to two miles south of Jonesboro the hills are capped by heavy deposits of gravels,

mainly chert with many cobbles of sandstone, all of which are commonly cemented into a conglomerate. None of the loess clays were found nearer than thirty feet or more of the top of these hills, but they often abut against them, thickening towards the valleys. From this point, two miles south of Jonesboro, northward to the Missouri line, the pebbles are bleached, especially when they occur in wooded tracts, as they do here. These bleached gravels cover the hillsides and often form the road beds along the hilltops. Underneath them are characteristic cross-bedded party-colored sands often alternating with thin beds of potters' clay. The bleaching process rarely extends to the underlying sands, indeed it has been noted in but two or three places where the conditions were unusual. This bleaching is especially interesting in this region because it aids in understanding the origin of the limonite in the clays of the bottom lands of the creeks.

Attention has been frequently called in this report to the fact that the chert and other gravels of the Orange Sands are discolored with iron peroxide. Now these bleached gravels are the same materials from which the color has been removed. Such changes are common in iron stained superficial gravels. The chemistry of the process is about as follows: the organic matter falling from the trees as leaves, and derived from the decay of other plants is carried down by the rainwater through the gravel beds and reduces the iron salt from a peroxide to a protoxide, the latter is then changed to a carbonate by the free carbonic acid present; the iron carbonate is soluble in water and is removed by seepage or by surface drainage. The upper portions of the gravels are thus rendered quite colorless or white, in short, are bleached. But there are other important changes in waiting for the solutions of iron carbonate. When they reach the lower lands there is a change which leads to the loss of the carbonic anhydride, that is it is now iron sesquioxide with water added, in other words, limonite. In this same manner, or in one closely analagous, the limonite nodules so common in the hard-pan clays and bottom soils of this region have been

made. The former iron stains of the hilltops have now become a soil characteristic of the valleys.

Section near Jonesboro.—Three or four miles west of Jonesboro, on the line of the Kansas City, Fort Scott, and Memphis railway, are several cuts across low spurs of the ridge. These cuts disclose only the loess clays, but show them better than any other section in the county. They may be here divided into three layers on the usual color basis, as follows:

Bed.		Total thickness.
1.	Silicious or sandy humus, with much clay.................	2
2.	Tough, red, clayey loess, much fissured, the faces of the fissures black with dendritic segregations of manganese. This member is removed for railway ballast and is so hard as to require blasting......................	7
3.	Looser, yet tough, more yellow soil, weathering into vertical faces..	15

This cutting is duplicated at several places. This one shows the characteristic mode of occurrence and coloration of the loess.

JONESBORO LOESS.

The following is an analysis of no. 2 of the above section:
Specimen dried at 110°-115° Centigrade.

Silica, (free and combined).........................	74.65	per cent
Alumina..	12.99	" "
Iron (ferric) oxide....................................	5.10	" "
Lime..	0.31	" "
Magnesia...	0.47	" "
Manganese..	trace	....
Alkalies, by difference................................	2.06	" "
Loss on ignition.......................................	4.42	" "
Total...	100.00	" "
Air-dried sand in air-dried clay....................	32.40	" "

This clay, which is arable, contains the highest percentage of iron oxide of any sample obtained in the ridge. Near the excavation was a sort of a kiln, used by the railway company for burn

ing the clay in the hope of hardening it sufficiently to make it available for ballast, and the fragmentary remains found about indicate that it burns to an intense red and becomes quite hard. The plant was abandoned after the burning of the first kiln.

The Orange Sands.—The only section seen in the Orange Sands about Jonesboro was in 15 N., 4 E., section 20, the northeast quarter of the southwest quarter. This section is exposed in a gravel pit, four miles north of the town, whence are obtained most of the sands used at Jonesboro for building purposes. For thirty feet below the tops of the gravel crowned hills occur the party-colored, cross-bedded sands, mingled with abundant chert pebbles. In large and numerous pockets the sand is clean, white and coarse. Among the gravels at the top of the pit are many large, subangular sandstone fragments and large pieces of fossiliferous chert. The fossils are all cross-sections of crinoid stems. Near the base of the hill of which the pit is a section is a small stream, and in this an exposure of a few feet of bluish clay believed to represent the Tertiary clay of the region. This is the only known Tertiary exposure in this neighborhood.

Tertiary quartzite.—The most interesting portions of Craighead county, from a geologic standpoint, are to be found on the western margin of the ridge in 15 N., 3 E. A single exposure in this township was studied by Owen and was reported on in the volume devoted to this part of the state.* Of this region Dr. Owen wrote as follows: "On section 9, township 15 N., range 3 E., close to William Lane's house there is also a low range of quartzose sandstone, probabably of the same date." He had already said on the preceeding page: "On section 10, township 17 N., range 4 E., near Sugar Creek, Greene county, is a remarkable protrusion of hard quartzose sandstone through the quaternary deposits. This sandstone has all the lithological characters of the Potsdam, or lowest sandstone of Silurian date, as it occurs on the Minnesota and Wisconsin Rivers in the Northwest." These two localities appear to have been the only

*First Annual Report of a Geological Reconnoissance of the Northern Counties of Arkansas, pp. 28-29.

ones noticed by Dr. Owen and they have been seen and studied by no other geologist until the present time. The reference of these rocks to the Potsdam or to any part of the paleozoic made the locality one of great interest, occuring, as it does, in the heart of a region of Pleistocene soils underlain by rocks known to be of Tertiary age. That interest increased as the studies of the writer in connection with the gravels of the Orange Sands disclosed an ever increasing abundance of sandstone masses in those gravels as the area of their exposure approached. There was also a concomitant increase in size and angularity indicating the origin of the cobbles which have been referred to so often as occurring from Helena northwards. These masses were always eagerly examined for fossils which might aid in their proper classification, but always with negative results. Often there had been found decomposed fragments in the midst of the gravels, showing every character of these rocks except hardness, but no other facts that shed any light on their ultimate origin. There was a peculiar satisfaction, therefore, in being piloted to the exact locality examined by Owen more than thirty years ago, and by the William Lane mentioned by him. To one who has seen the Potsdam sandstones of northern New York there is nothing surprising in the reference of these rocks to that horizon by Owen. And yet there is absolutely no other than lithologic evidence upon which to base such a classification, and such classification is altogether erroneous in this case.

The locality is at the foot of a high spur of the ridge, forty feet or more above the Cache bottoms. The hills are high and crowned with heavy beds of gravel which, in turn, is overlain by a thin sandy and gravelly soil supporting a strong growth of the common short leaved pine and much scrub oak. Against the hillsides abut thin deposits of a loess clay, the meagre representative of heavy beds, most of which have long since been eroded away. Mingled with the clays are many strata of party-colored sands with some pebbles, these strata representing the rearranged and transported materials which were formerly spread either over its top or along its sides. The locality is characterized by numerous deep and narrow ravines, on the sides of which is spread

a thick coating of bleached gravels. The quartzose bed is a huge mass of a very hard rock, ringing like clinkstone when struck with the hammer, having its sand grains and pebbles well water-worn and showing structural features always recognized as resulting from the action of strong currents. On its surface this large rock shows a strong dip towards the west, but it was soon found that this was not a real dip but one made by the planes of false bedding. A few hundred feet north of the road, in a deep ravine in which the rock is exposed, the sandstone outcrops as a series of ledges from near the level of the bottoms to a point two thirds of the way up the hill, thus showing a thickness of fully ninety feet. The strata are from six inches to five or more feet in thickness and are nearly or quite horizontal. The total exposure of this particular outcrop of these rocks to the north of the point at which it was first seen is about half a mile in length. They never descend to the level of the Cache bottom though they are very near it at certain points. At this locality no exposure of the underlying strata could be seen, but a section beneath non-indurated sandstones of the same age exposed on a small stream about three miles south of this locality discloses the horizontally stratified clays of the Tertiary.

There are two or three less important outcrops of this same sandstone between this point and the south boundary of the township. Not far from their southernmost exposure, in section 29, the southeast quarter of the northwest quarter, are the heaviest beds in Greene county. At Lane's they form a spur of the ridge, and outcrop along the sides and near the head of a deep, but short gulley, where they form beds about eighty feet in thickness, the individual layers of which are from three to five feet in thickness and horizontally disposed. The origin of these quartzites is treated in chapter XII., of this report.

Buffalo licks.—Near this last locality, on the top of the hills, are found the usual heavy deposits of coarse, bleached chert, with occasional purplish quartzitic fragments, and pockets of pure white sand. Not far from the head of this ravine is a "buffalo lick," a characteristic feature of this part of the ridge. It is simply a deep pit-like place opening toward the Cache, with

vertical walls of sand below, followed above by the Orange Sand pebble bed, and this in turn is surmounted by a thin covering of siliceous humus which presents some of the features of the loess and doubtless represents it. This so-called lick was formed, as all such places are in Crowley's Ridge, by springs issuing from beneath the pebble bed and compelling enlargement of the lick by land-slides, and the subsequent removal of the fallen material.

Southernmost exposure of quartzite.—The last quartzite outcrop to the south, in this portion of the ridge, is about one eighth of a mile south of where the line of the Kansas City, Fort Scott, and Memphis railway enters the west side of the ridge. Here the individual beds are but a few inches in thickness, but they aggregate about forty feet. It is not so hard or so white here as it is further north, and its presence is first known only through the small fragments found as a talus in the bottoms of the ravines.

The ridge becomes much lower south of this last exposure of quartzose sandstones, and the western slope becomes far more gentle until it finally merges into the lowlands of Eel River. Two miles south of that stream the hills rise again to about two-thirds the highest elevation noted, and then bear away to the southeast, practically disappearing in 18 N., 4 E., where they are but little more than a system of small foot-hills.

The northernmost exposure of quartzite.—These quartzitic rocks have been traced from the southern limit above indicated in 15 N., 3 E., section 32, by means of outcrops a few miles apart, to 19 N., 6 E., section 19, where they appear for the last time as indurated sandstone. They here outcrop in and extend across the road and disappear to the west in a low hill a few feet above the Cache bottoms. To the east the outcrop extends for several hundred feet into the ridge, as traced in a deep ravine, and is surmounted by a two foot layer of exceedingly hard, fine grained, flint-like sandstone. This is the most northern exposure. Throughout this distance they preserve well the peculiar features shown at Lane's, appearing only either in the sides of deep ravines, at their head, or, in rarer instances, at the very

tops of the highest hills. These several localities will now be described in detail and their influence in determining the limit of the ridge to the west thus indicated.

The distribution of the quartzite.—The following table of localities will give the reader the geographic distribution of the outcrops of these quartzites:

14 N., 3 E., sections 29, 6, 7.

15 N., 3 E., sections 31, 32, 29, 20, 16, 17, and 9.

16 N., 5 E., sections 4, 5, 17, and 19.

This is the most eastern outcrop of this rock, all the other known exposures being on the west side of the ridge, or but two or three mile within its western margin.

17 N., 4 E., sections 1, 3, 25, and 36.

18 N., 4 E., sections 13, 34, 35, and 36.

18 N., 5 E., sections 2, 4, 7, 8, 9, 18, and 30.

19 N., 6 E., sections 19, 20, and 29.

The geologic features of these several localities repeat each other so closely at the different exposures that an account of two or three of the more important ones will serve to show their characteristic features.

In 17 N., 4 E., sections 10 and 11, is the outcrop of rock spoken of by Owen in the reference on page 90. The locality is at one of the highest elevations in this part of the ridge, and on a steep and rocky spur of sandstone which stands fully one hundred and fifty feet above the valley. The rock is, in places, very coarse, white on a fresh fracture, and exceedingly hard, some strata chipping with difficulty. The surface of the rock is somewhat irregular, being pitted and grooved more or less by weathering. The slight dip to be seen at the hill top, is not a true dip but one caused by the erosion of certain of the underlying strata allowing a large mass to fall into the position in which it now lies. It is to be remarked in general in regard to the dips to be seen on the margin of these hills that they change with the orientation of the face of the hill. The outcrop at this place, however, is the most massive and characteristic of all those to be seen in the ridge. Near the base of the hills the sands are soft and finally are loose, and are underlain by stratified blue clays,

similar to those seen in all other sections which disclose the bottom layers. Crowning the whole is a very hard rock, of variable thickness, but usually about two feet, which appears to be the chief protection to the underlying strata against such subaerial erosion as the region shows to be in progress. The outcrop forms the greater part of a hill about fifteen hundred feet in length the upper beds of which are broken off into immense masses which slope away from the hill, here in one direction, there in another. The hilltop is covered with a deep layer of cherty pebbles, except at the extreme western limit, which is crowned by sandstone. The slopes on either side of the spur are likewise covered with gravels among which are many very large masses of sandrock derived from near the top. The whole spur is surmounted by a thick layer of very hard, flinty, fine grained sandrock which contains the only evidence of fossils to be discovered at this locality. This evidence consists of a single imbedded fragment of wood or of a plant with woody structure, found near the very highest point of the outcrop. This fossil is Tertiary and sufficient to determine whether these rocks belong to the paleozoic or to some other part of the geologic column, but it does not enable one to determine to what portion of the Tertiary these beds must be referred. The evidence which is wanting here, however, is supplied by other sections not far away.

Fossil plants.—One of these localities at which fossils occur, is in 18 N., 5 E., section 30, the northwest quarter of the northwest quarter. It is about half a mile from Hardy's Mill, and on the face of a steep hill fronting west. The outcrop is a coarse sandstone, capped by a compact, fine grained, very hard sandstone, containing numerous casts and impressions of vegetable origin. While there is a rude resemblance to certain forms of water plants in the character and arrangement of these remains there is not left sufficient structure on which to base an opinion as to their real affinities. But below this siliceous layer there is a heavy layer of sandstone of coarser texture, and not so much metamorphosed, in which occur numerous remains of fossil plants. Those remains are mainly in the form of impressions

of leaves of dicotyledonous plants. Specimens of these plant remains were collected and sent to Professor Lester F. Ward of the U. S. Geological Survey at Washington, for study. Professor Ward has examined this material, and the following is his letter concerning it:

UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C., November 5, 1889.

Professor J. C. Branner,
State Geologist of Arkansas,
Little Rock, Arkansas.

MY DEAR SIR:

Your box of specimens came at a very busy time and it has been impossible for me to attend to them sooner. I have now examined them as fully as I have time to do at present, and find them too meager in amount of material to justify any very definite statements. I have had good pencil sketches made of all of them and have compared them carefully with all the American species known, and I am satified that none of them have been described before, and yet I would hesitate to name them as new species without more material. While this renders them more interesting from a scientific point of view, it greatly diminishes their diagnostic value to geology, which is your special point of view. If I could have found one species identical with what has been reported from any of our beds it would have had some weight, but this I cannot do. Two of the specimens from Hardy's Mill (white sandstone weathering green) certainly belong to the genus *Magnolia*, and probably to the same species, but of one there is only a fragment.

There is one other specimen from Hardy's Mill, a leaf without margins, but whose deeply sunk veins denote a different genus from the others. It is probably an oak, but indeterminable. The little narrow leaf from the last named place showing no nervation except the midrib and all the upper part wanting is probably ericaceous, perhaps *Kalmia* or *Andromeda*. but nothing can be said about it. Then there is a very definite little fruit or calyx, I think the former, which looks familiar, but I have been unable to match it as yet. I hope to do so eventually. It

seems to be an open 5-celled capsule seen from below, each of the cells dehiscing part way down a median dorsal suture. Our fruit collection is not arranged and I will have to have more time for this specimen. The only other thing is a rock, also from Hardy's Mill, exhibiting only stems lying at several angles with the plane of fracture. Some of the wood is well preserved and might show structure, but it would take a good while to prepare a slide and the result would probably be negative when reached.

You will readily see that the above account gives no clear clew to the age of any of the beds. They appear to be all of nearly the same age, and as you say, "probably Tertiary." I hoped to find some of the Mississippi Tertiary species or Laramie species, and a large collection might reveal such. The facies, I should say, was Lower rather than Upper Tertiary, i. e., there are no beech, chestnut, birch or hornbeam leaves, and I doubt whether it is equivalent to the Green River deposits of Colorado and Wyoming. All I dare say is that the very slim data at hand rather point to the base of the Tertiary as the probable age of these beds.

Yours, very truly,

LESTER F. WARD.

This judgment of Professor Ward confirms the reference of these beds to the Eocene Tertiary. The Hardy's Mill locality is the only one at which fossils are known in the whole extent of these sandstone beds. The various outcrops of this rock have therefore been correlated on petrographic and stratigraphic data alone. But the clue given at Hardy's Mill was followed for thirty miles and there can be no reasonable doubt but that these quartzitic sandstones are all of the same age, that is, Eocene Tertiary.

CHAPTER XII.

GEOLOGIC SECTIONS NORTH OF POINSETT COUNTY.—*Continued.*

Section on Beech Creek.—In Beech Hollow, which is in 18 N., 5 E., section 30, is a section which continues that at Hardy's

Mill downwards into the underlying clays. The locality is known as the Lovelady place. About sixty feet are exposed as follows:

Section at the Lovelady Place.

Bed.		Total
1.	Light colored, thin soil, with much chert, supporting a heavy growth of pines..................	2
2.	Hard, coarse sandrock, identical with that at Hardy's Mill; weathering greenish, softer below, regularly stratified.......	10
3.	Soft, cross-bedded, party-colored sands, red predominating, with numerous irregular patches of pure white sand, a little clayey below.........................	20
4.	Clay, sandy at surface, less sandy below, light drab in color, becoming darker below and ending in a bed of lignite; the whole is regularly and horizontally stratfied.....................	25

Near by the clays which underlie the lignite are exposed and are more indurated than usual, being almost a hard shale breaking with a conchoidal fracture. The most interesting feature presented by this locality consists in the gradual transition in the Tertiary from soft sands to the hardest sandrock. In several places where the sands are indurated on their exposed surfaces they are soft and loose within. The Hardy's Mill locality is only half a mile, or less, from the Beech Creek section and the two have been so connected as to prove the continuity of the beds exposed at the two localities.

Waterworn material.—Another very characteristic feature presented by the hills on this part of Greene county consists in their being capped, especially the highest, with very heavy deposits of Orange Sand gravels, cherty, and entirely free of sandstone pebbles. These gravels are well bleached, often quite coarse, and generally coarser than is customary farther to the south. They are associated with an abundance of fine white sand, and are often cemented together with oxide of iron. Every one of the higher hills and ridges thus capped with gravels and sands is covered with a growth of pines. These

generally keep well to the top and rarely descend far down on the hillsides. Loess, or any soil representing it or derived from it, is absolutely wanting. There are, however, deposits of loess to be seen well down towards the bottom on the west slope, where all its characteristic features are shown except the single one of fossils, but these deposits are neither continuous nor more than blankets. They have not been found higher than two-thirds of the total height of the ridge and occur so but once or twice. When seen best the loess of this region fills hollows in ravines, such as have by some means escaped the usual comparatively recent erosion of the district. Near the mouth of Beech Creek, or rather near the point where that stream leaves the hills, is the heaviest bed of loess seen on the west of the ridge. It is distinguished by an unusual number of calcareous concretions.

Vertical distribution of the quartzites.—All the outcrops of the quartzitic sandstone occur in about the same position in the hills. They are to be found as spurs, extending in various directions from the main axis of the ridge, or at the heads of ravines. They may extend from the bottom of the hill to near the top, or they may form a layer only a few feet in thickness at the top. In every case the outcrops are found surmounted with very hard layers which are usually from one to three feet in thickness. In several cases the rocks pass into soft sands beneath and these in turn give way to the ordinary Tertiary clays still further down.

Origin of the quartzites.—This species of metamorphism by exposure appears to be similar to that described by Dr. J. C. Branner, Director of the Survey, as occurring among the rocks of Tertiary age in the Sergipe-Alagoas Basin of Brazil. His destription of that locality fits so exactly many of the features presented by the rocks of this part of Crowley's Ridge that they are here quoted. Dr. Branner writes as follows*: "The fact that there are compact, glassy quartzites among these Tertiary beds, might, if taken alone, lead one to surmise that this formation had undergone dynamic disturbances. Such, however, is not the case. These quartzites seldom or never occur forming

*Transactions of the American Philosophical Society, 1889, Volume XVI., pp. 419-420.

beds continuous over considerable distances, but are derived from soft beds of sandstone which become indurated here and there upon exposure, forming quartzite blocks. As the surrounding portion of these beds weather away, these blocks are usually left lying loose on the surface where they exfoliate somewhat under the same influence that hardened them. That this metamorphism is produced by weathering scarcely admits of doubt. [The beds which are metamorphised are high up in the Tertiary series,] the underlying beds being made up of soft, horizontally stratified beds of clays and sands. It is quite evident that these rocks have not been subjected to any unusual lateral pressure, such as that which so often produces metamorphism. The pressure from above is and always has been less than that upon the underlying soft beds of sand, so that its metamorphism cannot be attributed to pressure from above. The strongest evidence that this metamorphism is a process of weathering is found in the condition of some of the partially metamorphosed masses of sandstone. The writer has seen at three seperate exposures large masses of this glassy quartzite protruding from banks of soft sandstone, which, upon being broken off two or three feet beneath the surface of the exposure, showed the uncovered end of the block to be nothing more than sand in process of hardening, the mass becoming harder and harder toward the exposed surface. When these blocks are entirely separated from their surroundings and lie fully exposed to sunshine and rain, they become as hard as glass and have a similar conchoidal fracture."*

It would appear, therefore, that the metamorphosed condition of the Crowley's Ridge sandstones is to be attributed to weathering. True, there is no such weathering as will lead to the formation of round boulder-like masses but rather such as takes place with the whole of the beds of sands over limited areas. Most of the outcrops are local and cover but a few acres, but there is occasionally one a mile or more in length by half to three-quarters of a mile in width.

Quartzite on the east side of the ridge.—With one exception

*While the Arkansas and Brazilian Tertiary quartzites have a very marked similarity, the Arkansas beds are much more massive, and constitute a more striking topographic feature than do the Brazilian quartzites.—*J. C. Branner.*

all these metamorphosed sandstones are to be found on or near the west face of the ridge. The single exception is well toward the east margin of the ridge, on Eight Mile Creek, southwest of the town of Paragould. The exact locality of the first of these eastern outcrops is in 16 N., 5 E., section 5, southeast quarter of the northeast quarter, at the middle of a high hill. The beds are from forty-five to fifty feet in thickness and may be traced to the south for a distance of nearly a mile, exposed in gullies and on the sides of the higher hills. They are here coarse, ferruginous, rather soft, and weather into immense blocks weighing many tons. The oxidation is much greater on the surface than within. When very coarse the individual grains are seen to be well rounded and smooth. At the highest point, which is also the point of greatest thickness, the rocks form a cliff overlooking the valley of Eight Mile Creek. The face of the cliff is deeply etched.

Quartzites at Burton's.—A short distance to the north and east of this locality, on the southwest quarter of the southwest quarter of section 4, on the Burton place, in a hill which slopes gently westward and but a few feet above the general level of the creek bottom, the sandstones again outcrop, this time pure white in color, of flinty hardness, and in great detached angular blocks. They are fine grained, but are devoid of fossil remains. In an open field a few yards away are, deeply imbedded in cross-bedded, irregularly stratified mottled sands, many large masses of this sandstone, all well rounded, many of which would weigh half a ton or more. It was here noted for the first that these detached white masses were always found imbedded in mottled sands.

Quartzite, clay, and fossil plants.—An outcrop of some interest in which the relations of the Tertiary clays and the sandstones are clearly shown is exposed in 18 N., 4 E., section 13, on a small tributary to the Cache River in a north facing cliff. This cliff is a cross-section of a considerable spur of the main ridge and is capped by a very hard siliceous sandstone about three feet in thickness. This is underlain by a softer sandstone which erodes somewhat rapidly leaving the harder member to jut out

as a ledge until erosion has progressed far enough to compel it to fall of its own weight. The hill has become strewn with these immense blocks. Below the softer sandstone of this section the rocks are soft and at the base are replaced by a bluish Tertiary clay, with occasional partings of fine white or yellowish sand, which contain abundant scales of mica. Scattered throughout the clays are many small pieces of lignite. In the bed of the creek are numerous masses of silicified wood which has been identified by Professor Knowlton as coniferous and belonging to the genus *Cupressinoxylon*. On the highest ridges surrounding are the customary gravels with the usual pine growths and, mingling with the undergrowth, are found many specimens of the common brake (*Pteris aquilina*), and rare examples of cactus, (*Opuntia englemanni*).

Silicified stumps in place.—Another section of interest as presenting certain unique features occurs in 19 N., 5 E., the southwest quarter of the southwest quarter of section 35, in the margin of the ridge near the valley of the Cache. A hill of Tertiary blue clay, rises about forty feet above the bottom lands at this place. In cross-section these clays are regularly and horizontally stratified, with little or no sand. Imbedded in this clay, near the summit of the hill, is a large stump of silicified wood in place as it grew, with all its roots still imbedded and ramifying in every direction. Some fifty feet away, and at a point a little lower, occurs another stump, similarly disposed, and near at hand are two or three silicified logs. In the banks of a small stream, about three hundred feet south, are many fragments of silicified woods, some of which are very large. The largest of these stumps has a diameter of four feet and some of the logs are scarcely smaller. The complete erosion of the overlying Pleistocene and the upper members of the Tertiary sands, leaves this hill a singular feature of the ridge. Nothing like it has been seen elsewhere. A thin soil covers the clays and this supports a stunted growth of oaks. Samples of this wood were examined by Professor Knowlton, and were found to represent a new species to which he has given the name of *Cupressinoxylon calli*. It will be further discussed in connection with the lig-

nites at the end of this volume. The hills to the east of this locality rise high above the bottom lands, and are crowned with waterworn gravel. On some of them are found very extensive deposits of siliceous sandstone, which is especially marked at the heads of the great ravines.

Lignite.—On 19 N., 6 E., section 36, in a small stream which is but a few feet above the general level of the Cache bottoms is an outcrop of lignite about three feet in thickness. The outcrop is in the base of the hill and the bed disappears beneath the surface of the water. It is quite black when wet, but dries to a brownish black. It crumbles into small fragments on exposure to the air. Above it are about fifteen feet of Tertiary clays and above these the usual Orange Sands. A short distance down the stream it is underlain by a bed of light drab fire-clay. The same, or a closely related bed of lignite was struck in a well a mile and a half southwest of this point in the Cache bottoms. Lignite is frequently found in the wells bored or dug in the bottoms of the deeper ravines but at varying depths and with a variable thickness.

The following is a proximate analysis of this lignite:

ANALYSIS OF LIGNITE.

Water	14.185	per	cent.
Volatile matter	40.300	"	"
Fixed carbon	38.760	"	"
Sulphur	0.930	"	"
Ash (cream colored)	5.825	"	"
Total	100.00		

Character: Dull brownish black on outside, but brilliant lustre on a fresh surface.

The proportion of sulphur is very small, and the total amount of available fuel material, which is represented by the sum of the volatile matter and fixed carbon, is seen to be far better than lignites generally average. Blacksmiths in the neighborhood are said to have used this lignite with fair results in the commoner kinds of forge work.

General features north.—From this point on the northern

extremity of the ridge these general features are repeated throughout the whole distance, with the single exception of the metamorphism of the sandstones, which character is not to be seen north of 19 N., 6 E., and there it is less marked than at points to the south. The ridge is cut up with numerous ravines, rendering the hills both precipitous and high, all of which are crowned with gravels and these are sometimes conglomerated. Two and a half miles south of Boydsville are the highest lands of Clay county. They are covered with very heavy deposits of pebbles, cemented together with iron oxide, and forming great masses in the roadway, and constituting the very apices of the highest hills. They are frequently from thirty to forty feet in thickness and below them are the customary variegated sands. The bottom lands of all the creeks and streams crossed are clayey, abound in limonitic nodules, are wet and cold—the typical "buckshot" lands of the bottoms. The soil of the Cache bottom proper is the same sort as that found in the creek bottoms.

CHAPTER XIII.

GEOLOGIC SECTIONS NORTH OF POINSETT COUNTY.—*Continued.*

The Gainesville Region.

The region about Gainesville may be taken as the type of the interior of Crowley's Ridge, especially since all parts are almost the exact reproductions of what is there to be seen. This town is about the highest in the ridge, being something more than three hundred and fifty feet above sea level and near the central portion of the hills. The village stands on Tertiary sands, and as these are easily eroded the topography of the town is irregular. In the flood plains of all the streams the characteristic clayey or "buckshot" land is to be found, which is particularly marked along the road between Gainesville and Paragould, which passes through much low gronnd. These features are marked in the valleys of Eight Mile, Jack's, and Locust creeks. All this low "buckshot" land is characterized by a strong growth of post oak and willow oak. On the tops of the lower hills and

along the slopes of the higher ones are deposits of loess, but those deposits are not so heavy as they are upon the west slope. Whether they have been eroded more or whether they never were so heavy as on the west it is not possible to decide. The loess about Gainesville is more clayey, the iron much more oxidized, the absence of fossils marked, the concretions generally fewer, and its general facies somewhat disguised by the intermigling of sands and gravels from the adjacent hills.

The sections.—The sections available for study are all natural ones with the exception of one or two toward the western margin of the ridge on the line of the railway. The first of these sections is to be seen in the south edge of the village, in the side of a bluff facing north. It discloses forty feet or more of variegated, false bedded, coarse sands, interstratified with white or drab pipe clay, or with an accasional thin layer of pink clay. Above this sand bed is a light colored clayey sand, with yellowish, irregular patches of ochre scattered throughout. The total thickness of this member is about twelve feet. Above it is a reddish, tough or indurated clay, which represents the loess and is six or seven feet in thickness. At the top is the yellowish or reddish silicious thin soil of the higher portions of the ridge, mingled with which are abundant bleached chert pebbles. This top soil is usually only a few inches in thickness, but it sometimes increases to two feet or more.

Section at Gainesville.—In the west margin of Gainesville, in a deep gully, the usual stratigraphy of the slopes of the hills is exhibited in a characteristic manner.

Section in the Western Part of Gainesville.

Bed.	Ft.		Total.
1.	1.	Reddish, thin humus	1
2.	2.	Thin, loose soil, with abundant clay and some sand, not so red as the preceeding member	3
3.	2.	Reddish joint clay, with numerous small nodules of limonite near the top. This clay is the local representative of the loess	5
4.	6.	Variegated clay with much fine sand. This sand is	

		often arranged in pockets, from six to eight feet in thickness	11
5.	1.	Red to white sands interspersed throughout a sandy clay, containing a few small pebbles. The pebbles are more numerous below	12
6.	1.	Pebble bed, mainly of chert; pebbles mostly small and evidently derived from a bed of Orange Sand pebbles; contains much sand and some clay	13
7.	7.	Deep brick red, somewhat indurated sands, with a little gravel near the top. It has occasional layers of white and drab pipe clay, irregularly distributed through it and not uniform in thickness	20

In the Orange Sands about Gainesville are very many pieces of white sandrock but none were noticed in any of the gravels of the higher hilltops. Occasional fragments of chert, some of two or three hundred pounds weight, occur in the bottoms of the deeper gullies. In the beds of all the streams are great quantities of chert derived from the surrounding hills.

Brick clays.—The characteristic soils of the more gentle slopes are well typified by the soil used for the manufacture of brick in the west edge of the town of Gainesville. It is here about two feet in depth, and only the surface member is utilized in brick making. It is stripped down to a tough yellowish clay substratum which is a loess soil from eight to ten feet in thickness.

Discolored loess.—Wherever exposed on hillsides this loess soil washes badly and soon discloses the underlying sands with some clay and a few pebbles at the top. The pebbles so found are all bleached and are evidently rearranged. A peculiar dark brownish clay fills many of the deeped fissures in the older loess and traverse it in all directions very much after the fashion of veins. The origin of this dark brown clay could not be ascertained. A sample of it was taken for analysis, the result of which is given herewith.

LOESS CLAY.

Analysis of dark brown clay forming streaks in the loess, from Gainesville, Greene county.

Specimen dried at 110°-115° Centigrade.

Silica, (free and combined)	81.34	per cent.
Alumina	9.71	" "
Iron (ferric) oxide	3.67	" "
Lime	0.29	" "
Magnesia	0.33	" "
Manganese	trace	
Alkalies, by difference	1.55	" "
Loss on ignition	3.11	" "
Total	100.00	per cent.
Air-dried sand in air-dried specimen	35.00	" "

Even if this clay occurred abundantly it is not by any means certain that it would possess any economic value. So far as the analysis is helpful in determining its origin it seems to be only ordinary clay of the loess deprived of a considerable percentage of its sand, discolored with iron oxide and filling fissures into which it has been washed during rains.

Colored clays at Gainesville.—There are, however, about Gainesville, many more or less extensive deposits of clay, varying from a few inches in thickness to three or four feet, and in color ranging through all shades of red, pink, drab, and lead to white. On the road in the north edge of town at the foot of a hill, and extending into the fields on either side, is a characteristic outcrop. The colors of this clay range through all the shades of white and pink; it is pockety and of variable thickness, and while its exact extent could not be ascertained it was traced for more than fifty feet. Its analysis is given here:

PINK CLAY FROM GAINESVILLE.

Specimen dried at 110°-115° Centigrade.

Silica, (free and combined)	71.17	per cent.
Alumina	18.44	" "

Iron (ferric) oxide	2.77	"	"
Lime	0.25	"	"
Magnesia	0.44	"	"
Alkalies, by difference	0.90	"	"
Loss on ignition	6.03	"	"
Total	100.00	per	cent.
Air-dried sand in air-dried clay	14.52	"	"

The origin of the Gainesville clays.—The entire absence of manganese in this sample, when that substance occurs in almost all the other clays examined throughout the ridge, renders this analysis of great interest. It indicates, but not conclusively, that the ultimate origin of these fine pipe clays must be sought in deposits earlier than the Pleistocene and renders probable the correctness of the reference of the heavy beds of sand which contain them to the Tertiary. The associated Orange Sands, however, constitute the strongest evidence of their Tertiary age. Manganese occurs in the rocks of all ages, and is of the most erratic distribution. Considered alone the fact of its absence is not conclusive of the Tertiary age of these clays. The conditions under which such very fine clays are deposited certainly indicate that the waters transporting them must have had but little current. Alternating as they do with the coarse and fine sands of the region, which sands are false bedded in every possible manner, one is led to conclude that the beds of sand themselves have been deposited at various times and by waters in various degrees of turbulence. In this way only can be explained the alternation of clay and sand, the latter often containing blocks and masses of the former. Were other evidence wanting one would be led to such a conclusion. But evidence of a very positive character is furnished by a locality a mile and a quarter north of Gainesville, in a railway cut. In the cross-bedded sands of undoubted Tertiary age, which there form the base of the hills and appear in great depth in a gully adjoining are to be found vast quantities of white, slate colored, and purplish pipe clays, but all disseminated throughout the beds of sand as small, and sometimes angular fragments, from half a foot to

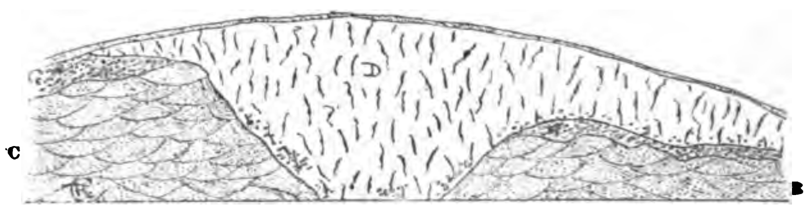
one foot in diameter. These masses are in two or three contorted zones and so arranged that their own lines of stratification form every conceivable angle with the stratification lines of the sands themselves. There is no doubt that the sands and clays were deposited together, but both were derived from the same beds. The beds as rearranged are Tertiary. Covering the lower part of this exposure is a regularly stratified bed of similar clays, with pebbles surmounting the whole. The bottom of the gully contains great quantities of these pebbles, all bleached, and among them large masses of chert. There are also found, in these gravels, a large mass of Carboniferous coral belonging to the genus *Lithostrotion*.

Between the railway cut just mentioned and Gainesville is an interesting cross-section of a low hill which shows the structure of the lower spurs, and, at the same time, indicates the relation of the loess and later deposits to the older members of the general section. The hard-pan, clayey soils of this low portion abut against the loess clays and here present a thickness of about six feet. Throughout its whole thickness it is charged with limonite nodules in great profusion, especially near the top. Over it lies a kind of modified loess, that is, a loess with both sand and clays added from the surrounding hills. Higher up on the hillside is the characteristic loess.

Section northwest of Gainesville.—The following is a section on the railway at the top of the grade about two miles northwest of Gainesville.

Bed.	Ft.		Total.
1.	3.	Reddish, sandy soil, bleached below	3
2.	4.	Redder, tough, clayey soil, with abundant coarse sand, fissured. This bed varies in thickness from two to four feet	7
3.	12.	Yellowish, typical loess	19
4.	3.	White sandy clay, with a few very small pebbles.	22
5.	2.	Reddish clays with some yellow and red sands	24
6.	20.	Red and otherwise colored Orange Sands to the bottom of the deepest gullies, with pebbles and clay near the top	44

This locality is about the highest in the roadbed of the railway as it crosses the ridge and for that reason the underlying clays are not reached. The section given above is several times repeated with varying details for two or three miles. This one differs from most of them only in that it does not reach down quite to the bluish and slate colored Tertiary clays which do appear in the railway cuts nearer the western margin of the ridge. One of these cuts seem to indicate that the clays of loess origin were here, as has been seen elsewhere, laid down upon partially eroded Orange Sands. The section is illustrated in the accompanying figure, and represents a cutting about two hundred and forty feet in total length.



Exposure in the railway cut two miles north of Gainesville, Greene County.

The locality is two and a quarter miles north of Gainesville. G is a layer of bleached but not rearranged Orange Sand pebbles, overlying C which is a cross-bedded variegated sand. D is loess filling an old channel of erosion in the Orange Sands, scattered along the bottom portions of which are a few pebble, derived from the beds surmounting the sands. At A is a continuation of the gravel bed, not quite so thick as G, and quite well bleached. B, which is the equivalent of C, is bleached quite white. There are in B and near its bottom a few layers of ferruginous sandstone. These sandstone layers are from one to one and a half inches in thickness and are evidently of recent origin.

The Poplar Creek section.—One of the lowest horizons at which the pebbles of the Orange Sand are to be seen in quantity is on Poplar Creek, in 16 N., 4 E., the northwest quarter of sec-

tion 10, where the stream flowing toward the western boundary of the section cuts across a low ridge. The bed of the stream contains an unusually large amount of the loose chert gravels derived from the cut which is about twenty-five feet high.

Section on Poplar Creek.

(16 N., 4 E., section 10, northwest quarter.)

Bed.	Ft.		Total.
1.	3.	Light colored, sandy humus, with a few pebbles...	3
2.	10.	Gravel bed with an occasionally well marked bed of clay. None of the beds extend across the entire section. Much coarse sand is distributed in the gravel..	13
3.	1.	Conglomerated gravels and sands............	14
4.	12.	Cross-bedded, variegated, somewhat indurated sands, white and yellow predominating. At certain points these sands are cemented by iron into very hard and compact masses of great extent. There are rare small masses of a slate colored pipe clay scattered through these sands. Below them are many large, lenticular masses of siliceous iron ore which are in a more clayey portion of the sands and evidently mark the point of transition to the underlying bluish clays characteristic of the sections of the more southern parts of the ridge	26

There is a similar section in 18 N., 4 E., section 13, in the bank of a stream which cuts down into the Tertiary clays for ten feet, disclosing similar masses of iron ore.

Soils and clays.—The east slope of Crowley's Ridge in Greene county, and along the greater part of its length in Clay county is very gentle with but few small and sluggish streams. Many of these creeks have rather wide valleys but disclose no geologic sections of interest. The soil is the usual whitish, clayey soil, abounding in buckshot, and lumpy when broken by the plow. This soil continues well out towards the St. Francis River, save on a few lenticular hills which rise a few feet above

the general level. On the slope the soils are somewhat better but still show the evidences of their origin in the siliceous Tertiary beds of the region. Limonitic buckshot lands abound wherever the subsoil is somewhat or largely clayey. The surface soils are used for brick manufacture, especially about the town of Paragould, which is low enough to have considerable deposit of loess on the smaller spurs surrounding the town. The following is an analysis of this brick clay. The same soil is cultivated in the vicinity of Paragould.

BRICK CLAY FROM PARAGOULD.

Specimen dried at 110°–115° Centigrade.

Silica, (free and combined)	79.07	per	cent.
Alumina	8.79	"	"
Iron (ferric) oxide	2.54	"	"
Manganese, red oxide	3.68	"	"
Lime	0.25	"	"
Magnesia	0.23	"	"
Potash and soda, by difference	1.89	"	"
Loss on ignition	3.55	"	"
Total	100.00	"	"
Air-dried sand in air-dried specimen...	43.64	"	"

The considerable amount of manganese in these soils may have some bearing on the fine coloration of the bricks made at this yard. As with nearly or quite all of the ridge soils this one is deficient in lime.

GEOLOGIC SECTIONS IN CLAY COUNTY.

Sections at Piggott.—From Paragould to St. Francis, on the Missouri line, there is but little change in the nature of the soils, and none in the geology of the ridge. In the heads of the innumerable shallow ravines about Rector and Piggott, there are occasional outcrops of gravels, but they are commonly much mingled with clays and sands and generally bleached, suggesting that the beds have been rearranged. The natural sections are all small and rarely deep enough to reach the underlying bluish clays On the ridge near Piggott, several wells have been put down

from sixty to sixty-five feet in depth, the records of which, so far as they could be obtained, show a general uniformity. The relations of various strata, as made out by their aid, is substantially the same, and about as follows:

Average of Well Records at Piggott, Clay County.

1.	Sandy soil with some clay	1 ft.
2.	Reddish locss, sandy below	15 "
3.	Variegated, red to white sands	30 "
4.	Gravel (not a constant bed)	1 "
5.	Clay, hard-pan	1 "
6.	White sands	12 "
		— "
	Total	60

These well sections of the lower ridges indicate that the gravel bed has been removed by erosion previous to the deposition of the loess, which, in them all, lies directly on the variegated sands which are commonly found beneath the gravel bed. The probability of erosion is further strengthened by the fact that all the sections which show the gravels are on the slopes of the ridge. The sands may, therefore, have been redeposited over them after such erosion occurred and before the loess was redeposited.

Payne Creek section.—A section of some interest is exposed on Payne Creek, near the village of Piggott, in 20 N., 8 E., section 32, the southeast quarter of the northwest quarter. The exposure is about seventy-five yards long with a maximum height of about thirty-five feet. At the top is the characteristic loess of the region, much bleached, beneath which are variegated sands of the Orange Sands deposits. These variegated sands interstratified with soft, small lumps of pipe clay which are so much oxidized that they resemble the common limonite of the buckshot lands. Pockets of great extent of pure white sands are seen near one end of the section under which is a pocket of white pipe clay about three feet in thickness and twenty feet or more in length. From the relations of these regularly stratified sands, and the clays, the entire absence of gravel and the fact that the

sands pass below the bed of the creek without disturbing the Tertiary clays beneath seem to indicate that the creek is carving a channel through sands not in place but derived from the surrounding hills. Since the locality is but little above the general level of the country, or exactly conforming to it, and since a similar sequence is seen in reported sections of wells put down in the St. Francis bottoms, not far to the east, it is quite probable that the whole region to the east, as far as the sunk lands at least, is underlain with this clayey sand representing the detritus of the ridge washed down before the loess was deposited. At all events no clays which can be correlated with the Tertiary have been found about Piggott in well sections; indeed none were seen which could, with certainty, be correlated with the Tertiary clays until the extreme upper limit of the ridge was reached at Chalk Bluff, where the St. Francis flows along the base of the hills.

Chalk Bluff.—Two miles north of the village of St. Francis the river is now eroding away its west bank and is disclosing the geology of the ridge at Chalk Bluff. This locality was visited by Dr. Owen, the former State Geologist, and the section reported by him was at the extreme north end of the bank, at or near the ferry. The following is the section of the bluff as reported by him:*

Dr. Owen's Section at Chalk Bluff.

Bed.	Ft.		Total.
1.	25.	Soil, subsoil, chert and hornstone gravel............	25
2.	96.	Pink and variegated sand, locally indurated into a soft, crumbling sandstone	121
3.	10.	White, siliceous clay shale or marly earth and five or six feet white potters' clay........................	131

When this section was observed by Dr. Owen, the total height of the hills was about one hundred and thirty-five feet. It is hardly necessary to say that no such section can be found now, so marked have been the changes made during the last thirty years at this locality. The highest existing point is scarcely more than seventy-five feet above the level of the river.

* First report of a Geological Reconnoissance of Arkansas, 1858, p. 20.

The following is the sequence now to be made out by building up the section from contiguous localities in ravines and along the river's bank.

The summit is crowned with fine gravel and coarse sands. The sands are all variegated, more or less indurated, false bedded where seen in good section, and are separated by thin strata of white and drab pipe clays into two or three beds of variable thickness. In places on the steeper and barren hillsides this clay is washed over the face of the hills and gives to them a white appearance, which, doubtless, gave the place the name Chalk Bluff. Along the river front and in the deeper ravines of the east face of the bluff are the regularly stratified bluish and drab colored clays of Tertiary age, containing a few fragments of lignite. No fossils of any sort were to be found. Erosion has been great enough to expose these clays along the river banks and to a height of thirty-five to forty feet in the deep ravines. Near the top of the bluff, on the west and east faces, the gravels are coarse, contain large masses of the chert which have abundant cross-sections of crinoid stems, and are locally cemented into a conglomerate. The section at this locality, therefore, practically stops at the upper limit of the Tertiary clays.

On the slopes of the hills west of the Chalk Bluff are patchy deposits of loess, and some occur also on the very tops of the low hills further to the south. The surface of the ridge in this portion of the state is generally under cultivation.

CHAPTER XIV.

THE GEOLOGIC HISTORY OF CROWLEY'S RIDGE.

The proper interpretation of the phenomena set forth with such detail in the preceding pages is beset with many difficulties. In the first place the area is a comparatively limited one when considered with reference to the great area of which it is but a piece and with which it is geologically linked and it has not yet been studied save in a most general way, and with reference to its relations to surrounding regions. In the next place the class of phenomena presented is unique, and though the facts are in,

intimate relation to certain features recognized as indicative of glacial action, the phenomena themselves are independent of such action. Then again the deposits studied in detail have not been studied in connection with certain related facts in the geology of the gulf coast, and it is, at present, impossible to connect them satisfactorily with the facts gathered by other observers in regions further to the south.

The northern and southern portions compared.—From a careful study of the sections taken north of Poinsett county the reader will infer that the general straitigraphy of that halt must be deduced from the superposition and comparison of many small sections no one of which gives the complete sequence of the members which make up the whole ridge. It will also be evident that the paucity, in most cases entire absence, of fossil remains renders the correlation of the several members exceedingly difficult, nevertheless that there is a close relation between the various strata must be sufficiently obvious. As a rule when beds are so nearly identical as to forbid their separation they have been considered identical stratigraphically and chronologically. This has been regarded as justifiable in so limited an area though it is doubtless open to serious criticism in more extended regions. Other evidence than this has been carefully sought, and was at first insisted upon, but it is not forthcoming, and cannot be, in the nature of the case. Bearing these facts in mind, it is believed that the following may be taken as the general sequence of strata for the northern half of the ridge, the section commencing at the tops of the highest hills, say in the western part of Greene county:

GENERALIZED SECTION NORTH OF POINSETT COUNTY.

1. A humus, largely siliceous, or a soil mainly sand. At the highest hill tops this soil contains gravel or may be entirely replaced by waterworn gravel.
2. Sands of Tertiary age, false bedded, party-colored, coarse or fine, banded often with drab, red or white pipe clay, or the last may be in pockets or lenses. These sands are generally loose, but in certain localities they have meta-

morphosed into a very hard glassy quartzite. The areas of metamorphism are distributed over many square miles but they are confined chiefly to the west side of the ridge.

3. Drab, blue, and black clays of Eocene Tertiary age, horizontally stratified, occasionally fossiliferous, the fossils being chiefly the leaves of deciduous trees. These clays contain rare beds of lignite of small extent and erratic vertical distribution. Moreover, the clays are commonly gypsiferous and are further characterized by abundant small plates of muscovite in the cleavage planes.
4. On the slopes of the hills, commonly less than two thirds of the way up, the section is modified by the addition of the characteristic loess of the region. In such cases the sands and gravels have been disturbed, locally, and more or less rearranged by the floods which deposited the loess.

The phenomena presented in the southern half of the ridge do not closely imitate those we have just described. They are intimately connected therewith, but are, in the main, somewhat modified. If local details be omitted, which will be justifiable in this connection, the general stratigraphy, as made out for St. Francis county, may be fairly accepted as that which is generally exhibited in this portion of the ridge. The sequence in that county is as following:

GENERALIZED SECTION IN ST. FRANCIS COUNTY.

1. A loess soil, with enough sand to render it decidedly silicious. This is the surface member and is usually of but little depth.
2. Typical loess, varying in depth from thirty to ninety feet, eroding badly, and presenting a characteristic loess topography. This member caps the ridge even at its highest points.
3. A clayey, pebble bearing, bluish or otherwise dark colored loess clay which forms the base of the typical loess deposits and probably marks the first stage in the loess deposition. This member varies somewhat in different

localities, being often quite thin and is even sometimes wanting. The pebbles are most abundant in the lowermost portion.

4. Party-colored sands, of variable fineness, often quite regularly stratified, sometimes overlying the pebble bed but usually occurring underneath it. The sand grains are well rounded. There are occasional masses or pockets of red, drab, white or yellow pipe clay.
5. Orange colored gravels, irregular in thickness, rudely stratified, sometimes well assorted so that only coarse gravels, or vice versa, are seen; there are occasional pockets or lenses of sand derived from the underlying member. In rare instances this bed lies directly upon the clays.
6. Blue, black, or drab clays, horizontally stratified, with small, sometimes large pieces of coniferous lignite. This member constitutes the greater portion of the body of the ridge. Along its margin it is to be seen only in the deepest ravines, or along the St. Francis and such of its small tributaries as flow from the ridge. It is often penetrated in deep wells, as at Forest City, and underlies the whole region. The lower exposed portion is fossiliferous, the fossils are marine and Clabornian in age. The clays are therefore Eocene Tertiary.

It is evident from these general sections that the lowermost members are not only lithologically the same, but are chronologically equivalent. While it is true that they rise higher into the mass of the ridge at its northern portion, it is also true that there they have suffered less erosion. It may be that very deep wells will yet discover fossiliferous zones among the lower members. If so, there can be little question as to what forms will be found.

Before entering upon the discussion of the differences between the northern and southern portions of the ridge, it will be well to call attention briefly, to the facts presented by the characteristic features of the ridge which are common to all parts of it. Special features have been already noted in connection with the detailed sections and do not require repetition at this time.

The features presented by the sands.—In the great majority of

cases the sands are loose or hardly coherent and are subject to extensive erosion and rearrangement. At divers times and in divers ways they have been modified so that they vary within wide limits. If widely separated localities are critically compared the degrees of differences, due to such modification, are quite marked, but are usually to be attributed to local causes. For instance, when gravels are found in the upper members of the sand series, which is by no means uncommon, it will at once be noticed that local denudation has been very considerable, serving to explain the occurrence of pebbles in beds commonly entirely devoid of them. But by far the greater number of sections studied show the sands as originally laid down. They also show, quite uniformly, a kind of plunge and flow structure which the geologist is accustomed to refer constantly to the action of the water in motion, either as waves, tides, or shallow water currents. In brief, all the facts in the case of the sands indicate that they were laid down in comparatively shallow waters.

Moreover, where the sands have been laid down upon the clays of the older Tertiary below them they contain much more clay and are generally regularly stratified. Sometimes they are so clayey, or perhaps it may be said the clays are so sandy, that the transition from one to the other is almost imperceptible. It is not positively determined for more than one locality in the northern part of the ridge exactly where the sands end and the clays begin. But certain it is that after a few feet vertically are passed, the sands are easily separated, become coarser, with little or no clay, and are generally less regularly stratified. As their top is neared they become variously interstratified, cross-bedded, and highly characteristic. In no case have fossils of any sort been found in these sands, except in the one locality near Hardy's Mill, in Greene county, where the sands form a sandstone, not a quartzite, like those on the west side of the ridge some miles away.

The characters of the gravels.—The gravel beds are of varying thickness, being deposited as a thin layer over a surface which indicates very considerable erosion at a period prior to their deposition. They sometimes fill depressions, at other times

they crown elevations, even the highest, and are commonly absent from slopes which show long continued erosion. Where both the gravels and sands are present the latter constitute the normal underlying beds, save on slopes where land-slides serve to explain a contrary position. Usually the individual pebbles are much oxidized, and are therefore generally of a brownish color, easily recognized even from a distance. They are made up mainly of a light colored chert, are generally well rounded or waterworn, rarely angular, always well polished. When in place they are always rudely assorted, cross-bedded, and mingled with more or less sand. Often the sand exists as great pockets of either coarse or fine material. There are occasionally to be noted pieces of a deep purplish quartzite, frequent agates, carnelians, vitreous quartz, and fragments of a white quartzite of sizes from a small bird's egg to masses of many hundreds of pounds. These latter are generally sub-angular, always highly polished, and superficially oxidized. They have been traced to the quartzites of Craighead and Greene counties, as the probable source of their origin. No pieces, either large or small, of northern rocks have ever been found in place in a gravel bed in Crowley's Ridge, nor has a rock bearing any evidence of glaciation been noted. Often the masses of chert are found to contain Carboniferous fossils, being mainly cross-sections of the stems of Crinoidea. But other forms are not wanting, several forms of corals and brachiopods having been found at various places. The gravels often contain large masses of silicified wood, mainly coniferous, but occasionally dicotyledonous, but these cannot be regarded as fossils properly belonging to the gravels, having doubtless been derived from the underlying Tertiary lignitiferous clays. Thus there is no paleontologic basis on which to correlate this member.

Outside our immediate area this gravel bed exists in great force and at great heights. Dr. J. C. Branner, State Geologist, reports it far to the west beyond the valley of the White and Black Rivers, on the tops of the higher hills. It is also found on the highest hills about the city of Little Rock, at one locality seven miles northwest of the city, at an elevation of abou

530 feet above tide. To the east of Crowley's Ridge it does not appear in the state of Arkansas at all, save in the sections along the Mississippi River, about the elevation of low water.

Thus in all the area between Crowley's Ridge and the escarpment made by the paleozoic rocks on the west, there are no deposits of gravel, so far as is now known, the exact equivalent of the Crowley beds, even at great depths. The same is true for the region embraced in the great flood plain east of the St. Francis River. When found in place in Crowley's Ridge this bed is always considerably above the general level of the country, reaching often to the very tops of the highest hills. This distribution should be constantly borne in mind.

The characters of the loess.—Comparing the accounts of the loess deposits as recorded for the two halves of the ridge, it will be noted that there is a difference in its vertical distributions. The highest hills, the deepest uneroded valleys, the slopes of all eminences in the southern half are covered often to a great depth with this characteristic loess soil. In some of the best localities presented for observation it is susceptible of division into an older typical loess and a newer or modified loess, the latter being derived from the former, and deposited at lower elevations along the flanks of the hills. In certain localities, as at Wittsburg, there is a well marked zone of carbonaceous matter, or old soil, marking clearly a period of erosion of the main body of the loess before the deposition of the higher portions which cap the ridge at that place. The newer loess is deposited over these differentiated layers. The differentiation of this lower Mississippi loess has been also noticed by President T. C. Chamberlin* and its bearing on the history of the region has been hinted at by him.

In the northern half of the ridge the loess does not reach to the tops of the highest hills, nor is there any evidence that it ever did ascend to their greater heights. It is found girdling the hills but in less heavy deposits than in the region further to the south. Also, there have been found no deposits, even in very favorable localities, of what, for lack of a better term we have

*Some additional evidences bearing on the interval between the glacial epochs. Bull. Geol. Soc. of America, Vol. I., pp. 470-471.

denominated the newer loess. Loess fossils have not been found in the northern half of the Arkansas portion of the ridge, but in all essential particulars it is otherwise typical loess. Found on the flanks of the hills which are in great part made up of Tertiary sands it is often quite sandy, indicating the nature of the erosion which has taken place since its deposition. It is not so marked a feature of the northern as it is of the southern area. In both areas the loess-kindchen or concretions are abundant, solid, and rarely entirely wanting. There are many facts, given in the preceding pages, which point to a common method of deposition.

The Tertiary clays.—The Tertiary clays are found beneath the beds of sand and quartzite in all portions of the ridge alike. In the northern portion they extend higher up into the main mass of the ridge than they do in the southern half. In both portions, but more commonly to the south, they sometimes immediately overlie the gravels, but such contacts are rare and are apparently local. As a rule they are horizontally bedded, showing only local dips due to land-slides, are often drab, blue, black or mottled in color. In rare instances, as along Beech Creek, in Greene county, they are somewhat indurated, especially toward their base. These clays are often interspersed with thin layers of fine white sands, with mica scales, are commonly gypsiferous, at the lowest horizons exposed in St. Francis county and in deep wells in other localities, they are fossiliferous. In certain places, as in southeastern St. Francis county, Craighead, Poinsett, Greene, and Clay counties, among the layers are found more or less extensive deposits of lignite, often covering many acres. These lignitiferous localities are of erratic vertical distribution and do not appear to be at all continuous. They are most numerous in the lower undisturbed portions, that is in those portions which have suffered less extensive denudation. These clays extend downward several hundred feet, as disclosed in deep borings along the margin of the ridge. They are found from the northermost limit to the extreme southern end at Helena. Perhaps the limit of one hundred feet above the mean level of the surrounding region is never exceeded by any of these

Tertiary clays and they are commonly much less. They are fossiliferous in a few localities somewhat above the base of the ridge but the fossils are, in such cases, the remains of an abundant vegetation and indicative of conditions similar to those prevailing in modern swamps.

The characters of the deposits west of the ridge.—In the lowland area west of Crowley's Ridge there are no extensive excavations, either natural or artificial. Along the greater water courses, such as the White and Cache Rivers, opportunity is often given to note the general nature of the materials which form the substratum at insignificant depths. As noted in the preceding pages an occasional deep well or other boring has furnished a little evidence by which to make out the general stratigraphy. In this region it is found that below a surface soil of a few inches to two or even three feet in depth, there is a hard-pan varying in depth from three to fifteen feet. Under this is a clayey sand, or rather perhaps, a sandy clay, followed at the depth of twenty or thirty feet by a white sand which is the water-bearing stratum of the region. If this sand layer be penetrated to a depth of from eighty to one hundred and ten feet a gravel bearing sand is reached, the gravels being irregularly distributed and commonly small, but usually of chert. Beyond this depth no reliable facts have been gathered. The soils below the surface hard-pan are such as would be derived from the intimate mixture of fine sands and abundant clays. In all this area there have, as yet, been discovered no rocks bearing evidence of glaciation or of having been transported from glaciated areas. There have, however, been found examples of rocks foreign to the region under consideration. A steam shovel at work on the Memphis and Little Rock railway on the west side of the Cache River, in 3 N., 4 W., the southwest quarter of the northeast quarter of section 36, uncovered seven small boulders of crystalline rock, examples of which were brought to the office of the Geological Survey by Mr. E. C. Buchanan. Most of the pieces were about the size of one's fist and the largest is about two feet and seven inches by fifteen inches. The largest of the masses is a porphyry exactly like some of those quarried in Missouri on

the line of the St. Louis, Iron Mountain, and Southern railway. One of the smaller samples brought to the Survey office was a fine grained granite. All were found about six feet below the surface lying upon a clean fine yellow sand. The circumstances of their discovery seems to preclude the probability of their being recent transportations, and some natural cause of transportation connected with the physical history of the great valley must be sought. Throughout this extensive area, which includes many thousands of square miles, there are, near the streams, great deposits of alluvium and of river silt. The general surface of the region is flat, with long low swells, a few rods in width, whose principal axis is approximately north and south.

The characters of the region east of Crowley's Ridge.—Information in regard to the region east of Crowley's Ridge is not voluminous. Already there have been made references to the work of the Mississippi River Commission in the preceding pages. The geological work done by that organization has been neither complete nor extensive but it has given usvaluable data respecting regions unaccessible for the purpose of geological examination. The general level of the country east of the ridge is lower than that of the regions west of it. The surface soils are almost entirely alluvial, are wet and liable to annual overflows. As disclosed in the numerous borings made by the Mississippi River Commission the sections for this area may be typified by that at Helena, given on another page in this report. (See page 46.) The differences consist in the absence of the fossiliferous beds which were disclosed at the bottom of one of the Helena borings by means of which the lowest accessible deposits at that place have been correlated with the Tertiary. The Mississippi bottoms deposits seem to be made up largely ot a black sandy clay, with abundant carbonaceous matter derived from decaying vegetation, varied with sand more or less pure, in which are to be found a few scattered pebbles, mainly of chert. So far as definitely known there are no typical marine deposits in the upper members of the great trough, that is to say, for the first two hundred and fifty feet. The age of those lying below that limit

is still a matter of conjecture unless the Tertiary scarp indicated by the records of the borings at Helena and the deep well at Memphis is but a comparatively small affair. In that case we must suppose that the Tertiary underlies the whole valley from the ridge to the highlands east of Memphis.

Summary.—We have then the following facts:

I. A wide trough extending from the highlands west of the White River, that is, from the paleozoic scarp, eastward to the region beyond Memphis.

II. A later and deeper trough east of Crowley's Ridge, the present alluvial region of the Mississippi.

III. A rudely triangular area, with its base to the south, divided lengthwise by Crowley's Ridge.

IV. A series of deposits older than the present terranes, now being eroded away by the Mississippi.

V. A series of deposits of the Pleistocene age capping the hills along the river on the east, but found only along Crowley's Ridge on the west.

VI. A gravel bed older than the loess which caps it.

VII. A great deposit of sands, sometimes loose, sometimes metamorphosed into quartzite, shown by their contained fossils to belong to the base of the Tertiary.

VIII. A series of clays, underlying the whole area, lignitiferous in places, sometimes fossiliferous, and, in the ridge, rising considerably above the general level of the country; in short a residuary Eocene Tertiary ridge.

CHAPTER XV.

THE GEOLOGIC HISTORY OF CROWLEY'S RIDGE.—*Continued.*

Correlations.

The loess.—Before passing to the interpretation of the facts given in the last chapter, the basis of the correlations adopted for these features may not be out of place.

The loess is unquestionably of Pleistocene age. It is believed too that it belongs to early Pleistocene times, and is the representative of the physical conditions which prevailed at that

time. That the period was a long one is shown by the great thickness of the deposits, the evidence of double submergence, as indicated by the old soil horizons, or even of triple submergence, as indicated by the fringing zone of modified loess seen in the southern half of the ridge.

The Tertiary age of the gravels.—The gravels must be entirely separated from the underlying sands. This separation is based upon:

1st, their somewhat erratic distribution;

2d, their varying altitudes;

3d, their ever changing thickness;

4th, the variable quantities of loose sands associated therewith;

5th, the variable degrees of fineness of these sands;

6th, the evident redisposition of many great beds of gravels;

7th, the fact that they are occasionally found overlain by heavy beds of sand but so only far away from the margins of their distribution;

8th, their common origin as shown by the fossils which occur so sparingly in them.

The majority of geologists who have studied these deposits regard them as being of Pleistocene age, but aside from the eccentricities of their distribution, their well rounded character, the peculiar bedding and the fact that they are generally held to represent the southern phase of the great northern drift, we know of no direct reasons for such reference. While it is perhaps not possible to assign perfectly conclusive evidence of it, we regard the Tertiary age of these deposits as unequivocal. In a certain sense they belong with the sands, but they are a much later deposit. Nothing of a paleontologic character, however, is known which will warrant this reference, nor, in the nature of the case, can such evidence be expected. The silicified wood is not a fossil belonging to the gravel bed for it is derived from the underlying lignitiferous clays, and it cannot therefore be considered as evidence of the age of the gravel. Confirmatory evidence has been gathered by Professor R. D. Salisbury in regard to the deposits along the lower Ohio and the relations of the

Orange Sands to the old and new valleys. The gravel beds are therefore considered as Tertiary. Their separation from the underlying sands is based partially upon their relations in many places to the eroded upper surfaces of the sand series at their point of contact.

The Tertiary age of the sands.—The sands are undoubtedly Tertiary, and they represent the Orange Sands of Mississippi which are placed by Dr. Hilgard in the Pleistocene. The following are the chief reasons for regarding the sands as of Tertiary age:

I. In many sections absolute continuity has been found between these sands and the underlying clays;

II. In two localities these sands have been shown to be fossiliferous, and these localities have been connected with others in which no fossils were found;

III. So far as a judgment could be based upon these fossil remains they "indicate the base of the Tertiary";

IV. So far as can be determined, there is absolute vertical sequence and uniformity in ascending order until the old surfaces of erosion are reached where they are covered by the gravels as above;

V. There is no great difference in the general characters of the various exposures, some of which are many miles apart when the north and south sections are carefully compared;

VI. There is complete absence of pebbles in undisturbed beds;

VII. The chemical argument, based upon the absence of the oxides of iron, the small quantity of lime and magnesia, all of which suggest long exposure to atmospheric influences.

The strong and decisive facts are the downward continuity of the gravels with the clays and the paleontological evidence.

The age of the lower clays.—The age of the lower clays as indicated by the few fossils found, is unquestionably Eocene Tertiary. The paleo-botanical evidence is abundant in many places, as we have seen at Cherry Valley, at Bolivar Creek, and in many other sections where there are well preserved remains of Tertiary plants, but in too poorly aggregated clays to permit

of transportation. The genera represented are all early Tertiary.

Interpretation of the phenomena.—These facts indicate the following succession of events in the history of the Crowley's Ridge region: During Tertiary times, when the lowest clays were deposited, there was a depression of the entire region. The waters were marine, that is salt, and moderately deep as is shown by the nature of the fossil remains. This period was of long duration, as men commonly measure time, as is shown by the great thickness of the clays, and the great development of the beds of fossil oysters. The waters of the Gulf of Mexico then extended far to the north, even north of the mouth of the Ohio River. This region was at that time the bottom of a great extension of the Gulf of Mexico, and formed a portion of it, and what is now the Crowley's Ridge region was sufficiently far removed from the incoming streams of fresh water which debouched into it as to be little or not at all affected by them.

The next stage in the history was a period of elevation or resurrection. The waters of the Gulf retreated to the southward leaving the great beds of clay as dry land. Through this area the Mississippi began to plow and the work of the removal of the sediments previously deposited began. Over the surface were many vast swamps in and around which grew immense coniferous trees, the remains of which are now found buried within the great beds. There were also some deciduous trees, dicotyledons, but these were less numerous. The Mississippi entered the great embayment just below Cape Girardeau and spreading into several considerable streams rapidly engaged in the work of denudation and removal. Two main channels were formed, one east, the other west of Crowley's Ridge. That is to say, such was their relation to what is now that ridge. The great valley through which flows the White, lower Black, Cache, and other smaller streams was then dug out. On the west the great trough of the Mississippi was dug deeper and wider than that of the Ohio to the east. At length the waters of the Mississippi cut through and passed to the east of the ridge and its work west of the ridge ended. The work of erosion was still continued, however, by the smaller streams which enter the old

valley from the west; the Black, the Current, the St. Francis, and others.

There followed another period of depression. Immense beds of sand were carried down by currents which flowed along the shores of the new gulf. These sands are probably of marine origin and the structure of the beds shows that they were deposited in strong currents or in waters greatly disturbed by tidal action and similar causes. The coarse character of some of the materials and the interspersed beds of fine potters' clay show that there were periods of flood and periods of complete rest or quiet. The mingling of great masses of this clay with the sands and their redeposition as seen in so many places indicate periods of great disturbance during which the clay beds deposited in quiet waters were torn up and redeposited.

Then followed a period of elevation when the beds were lifted up as dry land and the great beds of sand were worn away and carried seaward. In some places the sands become indurated, and acted as barriers to the erosive agencies at work along Crowley's Ridge. The indurated beds become prominent as a long series of hills, of differing elevation, none of which were very far above the general level of the surrounding country. The Tertiary, as exhibited in Crowley's Ridge, was, at that time, drawing to a close.

Another period of depression, and complete submergence followed, and the Tertiary came to an end with the great deposits of gravel which now cover the most of the country which has not been greatly eroded since that time. These gravels are cross-bedded and interstratified with sands in every possible manner, presenting thus evidence of the action of the waters in a state of commotion. The extent of this depression is suggested by the great height reached by these Tertiary gravels. This depression was followed by an elevation which brought the Tertiary history of the region to a close.

The next great event in the history of the region is known as the glacial epoch. At that time there was a depression and the region was covered with waters moving more rapidly at first, and

more slowly at the last, fed by the great ice-fields of the north and heavily laden with the silt which now constitutes the loess. The evidence of more rapid currents or of floods in the early part of the epoch, consists in the vertical distribution of the pebbles derived from the gravel beds which underlie the silt and indicating a rearrangement of the pebbles. The work of the earlier part of the glacial epoch was one of deposition in this region. This was followed by a land surface upon which were produced the soils which, according to President Chamberlin, mark the time and place of the interglacial period. During this time there was erosion and vegetation, the erosion being sufficiently great and long continued to remove from the great valley most of the soils which the earlier glacial epoch had deposited, in other words, the erosion of the great trench of the modern Mississippi was practically accomplished during this interglacial time. Then followed a later glacial epoch, during which the trench was partially filled. At the time when the refilling of the trench of the Mississippi was taking place, the newer loess described in the preceding pages was being deposited. The valley, as we have it, was finished after the glaciers retreated, that is, during the present epoch, and is, in its present form, the work of the great streams that flow through it.

Evidence of the partial filling of the two great troughs, the one east and the other west of Crowley's Ridge, is not wanting. In addition to the soils of the middle loess and the evidence furnished by the newer loess, is that afforded by the erratic crystalline rocks found in the valley of the Cache, and spoken of on page 123. These boulders were brought from the porphyritic areas of Missouri by floods, not necessarily by ice, but in other ways more natural to this region of comparatively low latitude. Trees are often torn from their foundations with great masses of dirt and rock attached, they float and drop these masses far from their place of origin. Such may, or may not have been the case in this instance, but the fact is that they are here, and in one way or another testify to floods. These are the catastrophes which laid down the present characteristic deposits in the region west of the ridge which, in another place, we have correlated with the

Pleistocene. Adapting the conclusions reached by President T. C. Chamberlin* to this region, the facts indicate that its altitude was low in the closing stages of the earlier or first glacial epoch; it was somewhat elevated in the interglacial time when the great erosions occurred, and, after that time, rudely measured by the cutting of the great trench, the later glacial epoch again poured its silt-laden waters down the trenches formed during the interval. The work of erosion is still going on.

Crowley's Ridge is, then, the residual product of long continued erosion. It is in no sense an upheaval, nor does it, in Arkansas, contain a rock of crystalline character or of paleozoic age. Its existence is due to the resistance it has offered to erosive forces which have leveled the greater part of the region. It stands now a silent witness to a history so wonderful that the imagination is taxed by any attempt to compass all its details.

CHAPTER XVI.

THE SILICIFIED WOODS AND LIGNITES.

Frequent mention has been made of fragments or masses of silicified wood found throughout the ridge, but most abundantly south of Clay county. Thus far none has been seen north of the southern boundary of that county, though this is, of course, but negative evidence regarding its distribution.† This fossil wood has generally been found in the beds of the streams which have in them great quantities of gravel derived from the adjacent hills, though, in two or three instances noted in the preceding pages, large masses have been found in place in the Tertiary clays. During the progress of the study of the various sections, it has become more and more clear that this wood had some intimate relation to the pockets or beds of lignite which are scattered throughout the ridge. It was early noticed that no lignite occurs in the sands or gravels above the clays, and that no detached

* Bulletin of the Geological Society of America, Vol. I., page 474.

† Judge J. L. Mack, of Paragould, reports silicified wood about three miles northeast of Boydsville, near the middle of the ridge. The locality is well toward the eastern portion of the county.

masses of silicified wood occur entirely in the clays. No such wood occurs in the clays of any locality south of the sections in the northwestern portion of Greene county, and there the overlying sands have been entirely eroded away and the stumps and logs, still in place, project above the upper limit of the clays. Whether they thus projected into the sands formerly above them is simply a matter of conjecture, and not capable of direct proof. As the investigation proceeded it became a favorite hypothesis that the silicified wood was transformed lignite, and that careful study, microscopically, would probably prove the hypothesis to be correct. With this thought in mind, collections of both lignitized and silicified woods were made and transmitted to Professor F. H. Knowlton, of the U. S. Geological Survey at Washington, who has given especial attention to the study of fossil woods. The various examples submitted to him have been studied, and a brief statement of the results reached by him is given herewith.

The examination shows that the two great divisions of exogenous trees, namely, the dicotyledonous and the coniferous, are represented in the silicified woods; the first by the genus *Laurinoxylon*; the second by the genus *Cupressinoxylon*; the former related to the laurels and the latter to the cypresses of the present day. The first genus is represented by several species. From the gravels in the bed of Bolivar Creek, and from those of Big and Little Crow Creeks come specimens of a dicotyledonous tree which Professor Knowlton has named *Laurinoxylon branneri*; from Rice Branch, near Wittsburg, comes one other new species, while a third comes from Red Bluff, on the Arkansas River. As yet these forms have no representatives in the lignites, and thus far they present only negative evidence as to their having been derived from the Tertiary clays.

The genus *Cupressinoxylon* is represented by the species *C. arkansanum*, from Rice Branch, and by *C. calli*, from the Tertiary clays northwest of Gainesville. This genus is represented also by specimens of lignite from the sections along Little Crow Creek which are identified with *C. arkansanum*. The other form has, as yet, no lignite representative, though Professor

Knowlton is positive that still other specimens are coniferous. In this case, therefore, there is absolute proof that the silicified and lignitized forms are identical specifically.

The opinion that the silicified wood was, in some way, to be connected with the lignites of the beds underlying the sands was suggested by Hilgard* many years ago. Speaking of the occurrence of fossils in the Orange Sands he says: " * * * The closest scrutiny I have bestowed on hundreds of extensive exposures, has failed to detect any fossil apparently peculiar to the formation as such. This might seem paradoxical enough to any one acquainted with the frequent occurrence of silicified wood in these strata; but it soon becomes quite obvious to an attentive observer, that the regions of frequent occurrence of this fossil in the Orange Sand are co-extensive with those in which fossil wood, either silicified—when imbedded in siliceous sands—or lignitized, occurs in the underlying lignitiferous-Cretaceous or Tertiary-strata. It is not unusual to find trunks of silicified wood embedded partly in the unchanged lignitic strata, partly in the orange sand; the portion contained in the latter being nearly or wholly deprived of carbon, while the part imbedded in the lignitic material is, if at all silicified, of an ebony tint and often contains pyrites." Again, "I am convinced that the greater part, if not all of this fossil is derived from the underlying strata and will be found represented in the their flora." The prediction thus made in connection with the fossil woods of Mississippi has now been verified in the formations of Arkansas.

Silicification of lignite.—There can be little question that the process of silicification has occurred since these masses were torn from the underlying beds by the waters which deposited the sands above the clays. As ordinarily understood the process is purely a chemical one and perhaps very slow. It consists in the replacement, atom by atom, of the carbon of the lignite by silicic acid, or silicon dioxide. It is by no means essential that the organic matter be unchanged when the process begins. If the belief that this wood represents what was once lignite be a cor-

*American Journal of Science, Third Series, Volume 41, p. 318. 1866.

rect one, then the process of silicification can occur in the case of organic matter which has already undergone a partial change. A reference in Phillips' "Ore Deposits", to the very valuable work done by Professor J. D. Whitney in connection with the auriferous gravels of the Sierra Nevada, seems to indicate that similar phenomena have been noted by that geologist in the far west. The paragraph is here quoted in full on account of its suggestiveness concerning the gravels of Crowley's Ridge. It reads*: "The most important chemical change which has taken place in these gravels subsequent to their deposition, is silicification, which becomes evident on examining the various organisms which are found imbedded in them. The quantity of wood buried in these detrital masses is very large, and by far the greater proportion of trees so found have been converted into opal. These tree trunks sometimes bear evidence of having been worn by the action of the currents which bore them along with the stony detritus in which they finally became enclosed. In some cases fragments of wood are met with which had been more or less completely converted into lignite previous to silicification. This partial conversion into lignite may often be observed in specimens in other parts of which direct silicification has taken place; so that the two ends of the same fragment may resemble, respectively, jet and opal. The transition from silicified wood to silicified lignite is, however, very gradual, although both often retain their original woody structure."

We are inclined therefore to regard these silicified woods as having been derived from the lignites of the underlying Tertiary clays. They can for this reason have little or no value in determining the age of the sands and gravels in which they are now found except as showing that the latter are much younger than the clays. The process is purely chemical, and yet it is one that aids not a little in understanding the presence of the great beds of siliceous materials which have been shown to occur in most of the sections reported in the preceding pages.

The lignites.—The lignites of the Crowley's Ridge region are all of Tertiary age, that is to say, all that have been studied

*A Treatise on Ore Deposits by J. Arthur Phillips, London, 1884, p. 4.

in situ are Tertiary. It will have been noticed that they occur in the form of outcrops along the streams and in gullies with an occasional bed appearing in wells. The thickness of these lignite beds is exceedingly variable. Usually they are less than five feet thick, though the Bolivar Creek beds in Poinsett county are seven feet or more in thickness. It is also noticeable that the vertical distribution of the several beds is irregular, some of them occurring high up in the hills, while others are at their base or below it. So far as traced all these beds are independent of each other, having been formed at different times, and they are generally in lenticular shapes, most of which cover but a few acres, and many of them but a few hundred square yards. Their chemical analyses show that the Bolivar Creek and Clay county lignites are the best. The poorest is that found in St. Francis county, 4 N., 4 E., on section 26. This latter has been analyzed with the following results:*

LIGNITE.

Analysis of brown lignite from 4 N., 4 E., section 26:

Water	10.215	per cent.
Volatile matter	40.70	" "
Fixed carbon	21.50	" "
Ash (gray)	25.65	" "
Sulphur	2.00	" "
Total	100.065	" "

The analysis shows it to have but little or no value for commercial purposes.

So far as the lignites which preserve woody structure have been studied they show that the prevailing forest types were coniferous. Thus far only the single genus *Cupressinoxylon* has been recognized. There has been no additional paleontological evidence of the age of the beds, since no fossils of any sort have been found accompanying these fossil woods. The probable physical conditions of their environment, from the pockety nature of the various beds, would be summed up in stating that the trees grew in a series of

*Analysis by R. E. Call.

small swamps, some of which may have been connected, but others certainly distinct. They endured for great periods of time, as is shown by the vertical distribution of the lignite beds.

CHAPTER XVII.

ECONOMIC GEOLOGY.

Iron ores.—There are no minerals of present or prospective value in Crowley's Ridge, and the geology is not of a character to lead one to expect such minerals. The numerous accounts of great deposits of lead, copper, iron, and whatnot that one meets so often have no basis of fact. The iron which occurs as limonite is too impure and too small in quantity to ever prove of value. There is likewise no possible use for that purer grade of ore which acts as a cement to the gravels wherever they are conglomerated. It is too small in quantity and too widely scattered to ever attract the attention of capitalists, even if its reduction were not attended with difficulties that put it quite out of the question.

The sandstones.—The Tertiary quartzites of the western portion of Craighead and Greene counties are used locally for underpinning and foundation works for dwellings. In a region almost wholly destitute of solid rocks of any kind the value of these deposits cannot well be over-estimated, notwithstanding the fact that their conchoidal fracture and cleavage detract somewhat from their value for that use. Owing to their hard, sandy nature, they are worked with difficulty, dulling the instruments employed in dressing them very rapidly. Then, too, most of the deposits are not easy of access, and all are at some distance from railway transportation.

A valuable characteristic of these rocks is their hardening on exposure to atmospheric influences. The color also changes from drab, or white, to red and brown, a change due chiefly to the oxidation of the contained iron and manganese. They seem to be well adapted to bridge building, and

would serve for heavy abutments for trestle work, as well as for architectural purposes.

Building sands.—Locally there are to be found a few great beds of excellent and clean building sands of all grades of coarseness, and generally of fair sharpness and angularity—features which a good building sand must possess. It is, however, somewhat remarkable, that in a region in which extensive beds of sand are so common as to form one of its chief geologic features that beds of good building sand are so few. None are known to occur suitable for building purposes nearer than five or six miles of Paragould, and an equal distance from Jonesboro. Usually too much clay or too many pebbles with the sand make its handling costly.

Glass sands.—Constant attention was paid to the various deposits of fine, white sand, in the hope that good glass sands would be discovered. But none were found, at least none which could be utilized for other than the manufacture of the cheapest and most common kinds of glass.

The following is an analysis of one of the most promising sands found in Crowley's Ridge: *

GLASS SAND.

Silica	97.77	per	cent.
Alumnia	1.56	"	"
Iron	0.48	"	"
Lime	0.34	"	"
Magnesia	trace		
Loss on ignition	0.14	"	"
Total	100.29	"	"

The locality from which the above sample was taken is in Greene county, on the Cache Valley Railroad, on 17 N., 4 E., section 10, on the north slope of a hill facing a small stream which is tributary to the Cache. The sands are very white, and the beds are the best yet seen. They are under-

* This analysis is by the St. Lous Sampling and Testing Works, and was kindly furnished the Geological Survey by Mr. C. F. Collins, of St. Louis, Mo.

lain by clay. The samples were taken by Mr. Richard Jackson, of Gainesville. The deposit is of Tertiary age.

The analysis shows this sand to be a very good article, but not one which is suited to the manufacture of the best white or flint glass now so commonly found in the markets. It would make an excellent bottle-glass sand, or even the cheaper grades of window glass could be made from it. Its product would be green in color but less deep than the common green bottle glass, owing to the small amount of iron present. With soda and lime added it would make a fairly good window glass.

Colored clays.—Frequent mention has been made of the beds or thin strata of yellow and red ochre which occur among the beds of party-colored Tertiary sands in many of the larger sections studied. The only use to which this clay has been put was for painting barns, for which purpose it has been used near Wittsburg. Ochre of a deep red color occurs abundantly near that place. This ochre has been analyzed by the Survey with the following results:

RED AND PINK CLAY FROM WITTSBURG.

Specimen dried at 110°–115° Centigrade.

Silica	69.55	per	cent.
Alumina	15.20	"	"
Iron (ferric) oxide	8.10	"	"
Lime	0.58	"	"
Magnesia	0.97	"	"
Potash	0.52	"	"
Soda	0.50	"	"
Phosphoric acid	0.20	"	"
Loss on ignition	5.72	"	"
Total	101.34	"	"
Water at 110°–115° Centigrade	2.24	"	"
Air-dried, fine white sand	25.48	"	"

The analysis suggests no valuable use to which this clay could be put.

Fire-clays.—Fire-clays occur under nearly all the beds of

lignite wherever they have been found in Crowley's Ridge. At the base of the great beds on Bolivar Creek, in Poinsett county, are found clays rich in alumina and which might be valuable for the manufacture of paving bricks, fire-bricks, sewer-pipes, and similar uses. The clay is light gray in color and contains but little grit. The analysis is as follows:

FIRE-CLAY FROM POINSETT COUNTY.

Specimen dried at 110°–115° Centigrade.

Silica	61.76	per cent.
Alumina	22.91	" "
Iron (ferric) oxide	3.32	" "
Lime	0.75	" "
Magnesia	0.90	" "
Potash	0.62	" "
Soda	0.38	" "
Phosphoric acid	trace	" "
Loss on ignition	8.75	" "
Total	99.39	" "
Water at 110°–115 Centigrade	4.29	" "

At the locality of the glass-sand mentioned above (17 N., 4 E., section 10), occurs a fire-clay a sample of which was analyzed at the St. Louis Sampling and Testing Works with the following results: *

FIRE CLAY FROM GREENE COUNTY.

Moisture	17.64	per cent
Combined water and organic matter	6.63	" "
Silica	70.43	" "
Alumina	19.15	" "
Lime	0.52	" "
Magnesia	trace	
Iron	1.70	" "
Alkalies	1.84	" "
		" "
Total	100.27	" "

* The results of this analysis were kindly furnished by Mr. C. F. Collins, of St. Louis. The sample was collected by Mr. Richard Jackson, of Gainesville, Ark., to whom the Geological Survey is greatly indebted for aid in prosecuting its work on Crowley's Ridge.

This clay could be employed for the manufacture of fire-bricks of ordinary grade, for sewer-pipes, tile work, and similar uses.

Brick clays.—Clays suitable for the manufacture of the common grades of brick are abundant throughout the Crowley's Ridge region. Nearly all those deposits in which the loess clays enter to any extent are well adapted for this use. If more care than is ordinarily expended were given these clays in the pits before moulding a far better class of bricks would be produced than those now being manufactured. The tempering of brick clays appears to be a prime factor in successful manufacture. Where clay is dug from the pits and immediately run through the presses, dried with little care and burned in a hasty manner, a good quality of brick cannot result, be the clays employed never so good. All experience with the loess clays shows that they need to lie for a long time in the pit or even in piles exposed to the tempering action of the atmosphere before they are ready to be pugged and moulded. If this care be exercised the bricks made from the Crowley's Ridge clays will compare favorably with the excellent bricks made of the same material at St. Louis, Memphis and elsewhere. The following are the statistics of the production of bricks for all places along Crowley's Ridge for which it has been possible for the Survey to collect them for the year 1889:

BRICKYARD STATISTICS OF CROWLEY'S RIDGE ROR THE YEAR 1889.

(Abstracted from Vol. I. of the Geological Survey's Report of 1889.)

Place.	No. of yards.	Make	Men employed	Average monthly wages.	Capital.	Output for 1889.	Price at kiln per M.
Forrest City..	1	Hand	10	$ 250	$ 250	400,000	....
Gainesville...	1	Hand	7	210	200	100,000	$8.00
Helena.........	2	Hand	50	450	10,000	2,000,000	$8 00 to $10.00
Jonesboro.....	4	Hand	36	1,800	2,500	2,300,000	$6.50 to $8.00
Marianna......	1	Hand	8	200	510	300,000	$9.00
Paragould*...	1	Hand	....	....	....	....	....
Total......	10		111 +	$ 2,910	$ 13,460	5,100,000	

*There is a yard at Paragould, but it has not been possible to get any statistics concerning it.

The soils.—To the farmer the chief economic interests center in the soils. As has been frequently said in the preceding pages, while some of the soils are excellent many are not among the best. Throughout the low country the lack of drainage renders the soils wet and cold, thus unfitting them for the most profitable cultivation. In deep valleys or ravines and in the flat lands along the streams the abundant limonite nodules render them uninviting. Along the base of the hills the soil contains many of the elements of the body of the ridge, and their character is immediately determined by the nature of the ridge in that particular locality. If it be at a place where the loess caps the summit, or exists as a heavy deposit along its flanks, the soil contains less sand, and is far more easily worked and more productive. If the area be at or near a locality where the Tertiary clays are being eroded and contributing to the formation of the surface soil, the soil will contain much clay and will be stiff and not especially productive. It will at once be seen, then, that a great variety of soils necessarily enter into a discussion of this feature of the resources of the ridge. Numerous samples were taken from time to time and many of these were chemically examined. Some of the results of the examinations have been given; the remaining analyses are given below.

It will be noted that most of the soils which have been analyzed contain available plant food in fair abundance, but the absence of sufficient drainage is probably a prime cause of the partial success with which their tillage is rewarded. The essential plant foods which are most readily removed from the soil by the growing crops are nitrogen, potash and phosphoric acid. If these be present in the soil in a form in which the plant can take and utilize them, good crops will be grown. It is rare indeed that a soil with all in sufficient abundance can be found. Now all of the subjoined analyses show but a small proportion of potash and phosphoric acid. They therefore indicate the nature of the fertilizers which must be employed to make them productive. Since many

of the samples came from comparatively new fields and are therefore fairly representative of the best soils of the region, it cannot be that the deficiency is due to exhaustion, but rather to radical defects in the soil.

TABLE OF SOIL ANALYSES.

No. I. is a cream colored, slightly gritty soil from a cultivated field within the city limits of Paragould.

No. II. is a light brown gritty soil from near the village of Harrisburg, 2 N., 3 E., section 25.

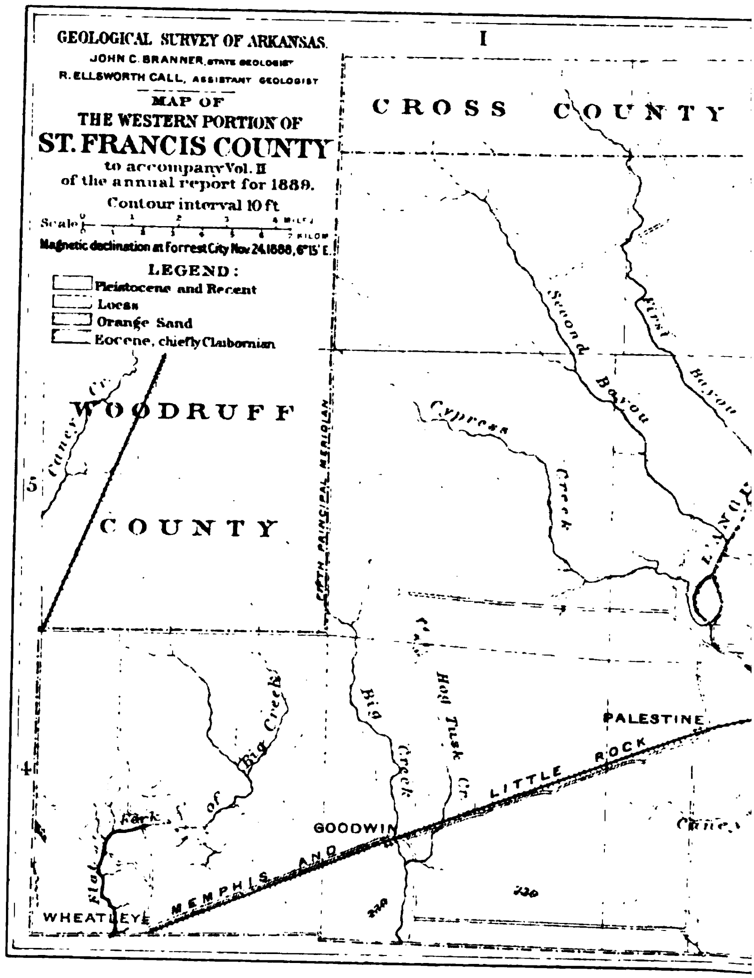
No. III. is a light colored gritty soil from the same region as the last, but constitutes the upper limit of the "buckshot" soil.

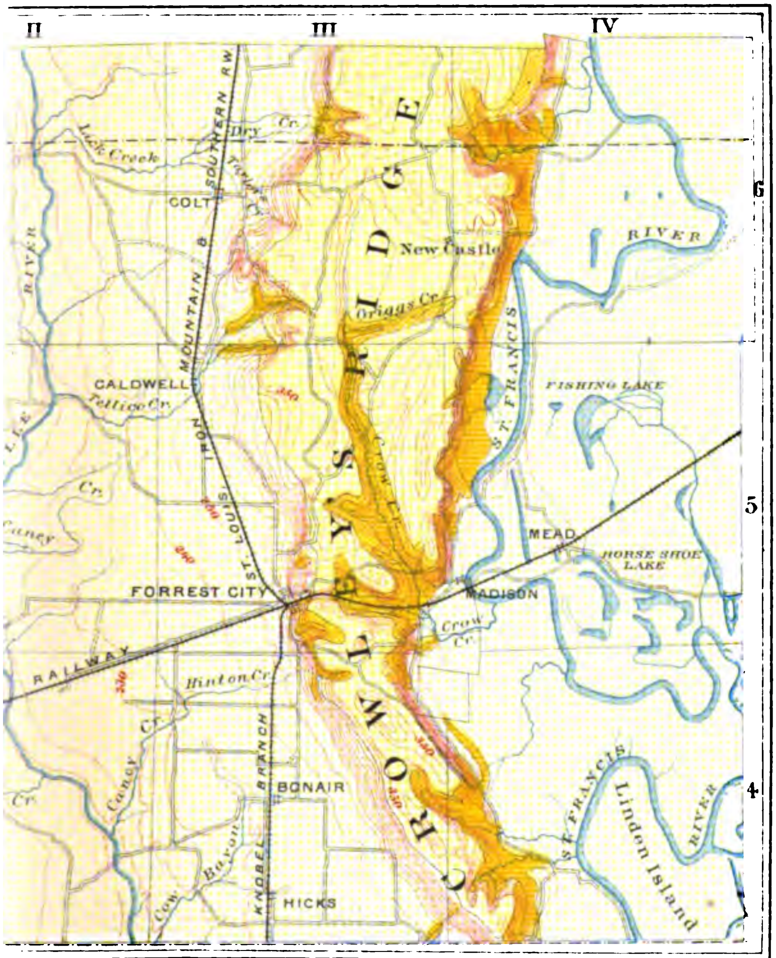
No. IV. is a yellowish, slightly gritty soil from one mile southeast of Marianna, in 2 N., 3 E., section 24.

Samples all dried at 110-115 degrees Centigrade.

Substance	No. I.	No. II.	No. III.	No. IV.
Silica, free and combined	76.20	75.93	87.50	75.46 per cent
Alumina	11.18	11.05	6.10	10.29 per cent
Iron (ferric) oxide	5.76	6 10	2.69	7.07 per cent
Lime	0.73	0.67	0.63	1.00 per cent
Magnesia	0.81	0.76	0.36	1.36 per cent
Potash	0.54	0.72	0.38	0 74 per cent
Soda	0.64	0.63	0.65	0.82 per cent
Phosphoric acid	0 20	0.20	0.13	0.30 per cent
Loss on ignition	3.85	4.56	1.95	3.18 per cent
Total	99.86	100.62	100.49	100.22 per cent
Air-dried sand	69.82	37.36	77.48	72.40 per cent

For other analyses see pages 18, 84, 85, 87, 89, 107, 108, 112, 137, 138, and 139.


GEOLOGICAL SURVEY OF ARKANSAS.
JOHN C. BRANNER, STATE GEOLOGIST
R. ELLSWORTH CALL, ASSISTANT GEOLOGIST
MAP OF
THE WESTERN PORTION OF
ST. FRANCIS COUNTY
to accompany Vol. II
of the annual report for 1889.
Contour interval 10 ft
Scale
Magnetic declination at Forrest City Nov 24,1888, 6°15' E.
LEGEND:
Pleistocene and Recent
Loess
Orange Sand
Eocene, chiefly Clabornian
I
CROSS COUNTY
WOODRUFF
COUNTY
FIFTH PRINCIPAL MERIDIAN
Second Bayou
First Bayou
Cypress Creek
Big Creek
Hog Tusk Cr.
Fork of Big Creek
PALESTINE
GOODWIN
WHEATLEY
MEMPHIS AND LITTLE ROCK
5
4


II
III
IV
6
5
4
CROWLEYS RIDGE
Dry Cr.
Lick Creek
COLT
New Castle
RIVER
Griggs Cr.
ST. FRANCIS
FISHING LAKE
CALDWELL
Tellico Cr.
IRON MOUNTAIN & SOUTHERN RW.
ST. LOUIS
Cr.
Caney
MEAD
HORSE SHOE LAKE
FORREST CITY
MADISON
Crow Cr.
RAILWAY
Hinton Cr.
Caney Cr.
KNOBEL BRANCH
BONAIR
ST. FRANCIS
Linden Island
RIVER
Cow Bayou
HICKS
Cr.
350
250
300

REPORT ON ST. FRANCIS COUNTY.*

CHAPTER XVIII.

TOPOGRAPHY AND HYDROGRAPHY OF ST. FRANCIS COUNTY.

The drainage of St. Francis county belongs directly to the Mississippi River system, though but a comparatively small portion of its surface waters flow directly into that that stream. The general slope of the land is to the south, and of course the principal streams flow in that direction. It is traversed from north to south by two principal rivers, the L'Anguille and the St. Francis, of which the latter is the more considerable. The tortuous course of the St. Francis, through the easily eroded alluvium of the Mississippi bottoms, is determined, with respect to its western limit, by Crowley's Ridge, the chief topographic prominence of the county.

The St. Francis River.—The drainage area of the St. Francis River east of the ridge is chiefly confined to the low alluvial and overflow lands which lie between it and the Mississippi. The only considerable streams which enter the St. Francis from the ridge are Big and Little Crow Creeks, both of which flow in a general south direction just east of the main axis of Crowley's Ridge and enter the river nearly a mile below the village of Madison.

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*The magnetic declination, or variation of the compass, was determined at Forrest City by the Geological Survey, Nov. 24th, 1888. The observations were made by Assistant Charles E. Taft with a Heller and Brightly mountain transit, and the declination was determined by observation on the elongation of Polaris. At 9 a. m., Nov. 24th, 1888, the declination was 6 degrees 15 minutes East.

The stones for permanent monuments not being ready, two stakes were driven in the ground about 125 feet apart with a small tack in the head of each. A line through these tacks is on the true meridian. The stakes are 400 feet west of the school house on the north side of the street in Forrest City.

The country east of the St. Francis is made up very largely of extensive bottoms dotted here and there with ponds, sinks, immense cane-brakes, and swamps, and is generally densely wooded. Because of the defective drainage these large swamps retain their water during a large part of the year, and much of the land is therefore too wet to be cultivated. These ponds and holes are often connected by a network of lesser channels, mainly deep bayous or sluggish streams, which ramify in every possible direction. These are often, again, connected with the Mississippi and serve both as inlets and outlets for the vast volumes of water that reach this stream during the great Mississippi overflows. Hence it is that the region in the immediate vicinity of the St. Francis, though the same conditions sometimes extend for miles to the eastward, becomes a vast stretch of sluggishly flowing water, broken only by great islands of cypress trees and an occasional area of a few acres of cultivated land rising but little above the surface of the water. These habitable portions, known locally as ridges, are narrow, but are often very long stretches of land, elevated usually from three to eight feet above the level of the surrounding country. The relative elevations of the two areas may be readily seen in the east-west profile across the county, along the line of the Memphis and Little Rock railway in Plate V.

Gravel bars.—In various places in the bed of the St. Francis occur great beds of gravel, mainly of chert, derived from the adjacent hills on the west. In some localities, as near Wittsburg, these beds are very large and almost solely composed of gravel with which is intermingled considerable sand. Prof. F. M. Webster, assistant entomologist of the U. S. Department of Agriculture, points out that these beds of gravel are the breeding places of the buffalo gnats that are periodically so annoying to live stock in the St. Francis bottoms.

Big Crow Creek.—Big Crow Creek occupies a deep but narrow valley cut in the ridge near its central axis. It rises near the north limit of St. Francis county and flows nearly

due south, until, near Madison, it bends suddenly eastward, enters the alluvial plain of the St. Francis and pursues a tortuous course until it joins the latter stream. During the very dry season it is, for the greater portion of its course, little more than a series of pools. Its bottom is composed almost solely of Carboniferous chert pebbles derived from the Orange Sands to the base of which, or below which its channel is excavated for the greater part of its course. These creek gravels lie directly upon Eocene blue micaceous clays, some layers of which are related chronologically with a widely distributed and rather thick *Ostrea* bed of Clibornian age. A few small, and for the greater part of the year, dry gullies add their waters to the volume of Crow Creek. The valley of this stream averages from half to three-quarters of a mile wide in its lower course, and much less than that in the upper portion. On either side it is flanked with bluffs, often precipitous, and from one hundred and thirty to one hundred and sixty feet in height.

Little Crow Creek.—Little Crow Creek is a short and comparatively unimportant stream which heads in Crowley's Ridge nearly a mile east of Forrest City and joins Big Crow Creek near Madison. The Memphis and Little Rock Railway is built along the bottoms of a flood plain of Little Crow Creek from near the head of the stream to near Madison.

The L'Anguille.—West of Crowley's Ridge nearly all the minor streams are tributary to the L'Anguille River, a sluggish and generally turbid stream, which crosses the county from north to south. Its bottoms are heavily timbered and occasional swamps of cypress occur along its course. In these places the river has, strictly speaking, no well defined channel but wanders about in a maze of lesser channels, occasionally spreading out into a thin sheet of water. The overflow limit of this stream averages nearly one mile in width, but in some localities it exceeds three miles. It has several minor tributaries, those from the east being Tellico, Caney and Taylor's Creeks, and, from the west, First, Second, and

Cypress Creeks. The drainage area of the L'Anguille occupies nearly three fourths of the county as mapped by the Geological Survey.

West of the L'Anguille drainage area the greater portion of the surface waters reach the White River through Big and Flat Creeks. These creeks drain all the prairie region west of Goodwin.

None of the streams of the county, with the single exception of the St. Francis, are navigable. This stream is open, practically, six months of the year to boats of three feet draught.

CROWLEY'S RIDGE IN ST. FRANCIS COUNTY.

General aspects.—Crowley's Ridge is the only prominent topographic feature in St. Francis county and, indeed, in eastern Arkansas. It crosses the country in a north-south direction, as a narrow ridge of loose and easily eroded material, which nowhere exceeds in breadth six miles, nor an altitude of one hundred and fifty to one hundred and seventy feet above the general level. Just south of the county line, in the northern portion of Lee county, the ridge dies away in a succession of low foot-hills which are finally lost in the alluvial plain of the L'Anguille, which here runs in an easterly direction to join the St. Francis a few miles east and south of Marianna. Near Marianna the ridge again becomes a conspicuous topographic feature, though its west slope is rather more gentle than in St. Francis county. With varying altitudes it continues as far as Helena, in Phillips county, where it ends abruptly in high bluffs close to the Mississippi River.

Surface features.—The general surface of Crowley's Ridge, in both its narrowest and widest portions, is very irregular. The main axis is both tortuous and undulating, depending, in the first place, upon the proximity of the St. Francis and Mississippi Rivers in past geologic time, and, in the second place, upon the nearness, sometimes identity, of the headings of the small ravines and gullies, of each slope, by which it is

everywhere diversified. The water-shed is generally close to the eastern face, save in the region drained by Big Crow Creek, where the principal water-shed passes to the west of that stream.

Throughout St. Francis county the features peculiar to the ridge at Helena, described on pages 36 to 46 of this report, are emphasized to a remarkable degree, a fact directly related to the genesis of the ridge as a topographic feature. Along the east face innumerable land-slides, both ancient and recent, expose the most nearly complete sequence of strata from the recent deposits to those of the Eocene Tertiary. The western slope of the ridge proper is much less precipitous, gradually dying away into rolling foot-hills or ridges, which are lost in the general surface within a mile of the axis. From the base of the ridge westward to the L'Anguille the descent is gentle, varying from ten to twenty feet per mile. Beyond that river the descent still continues, but is rarely more than three feet to the mile as far as Goodwin, where an equally gentle westward ascent is noticeable as far as Wheatley. Forrest City occupies the highest portion of the west foot of the ridge. The reader is referred to Plate V., where will be found full details in respect to slope and elevation for all points on the railway lines in the county. The western slope of the ridge is so gentle that it is inappreciable except as the result of careful leveling. The surface of this plain is characterized by the presence of innumerable, somewhat lenticular ridges, or swells, a few feet in elevation, and rarely exceeding eight or ten feet, which extend in a general north and south direction. This all has a direct relation to the Pleistocene or pre-Pleistocene geologic history with which they, in common with the ridge itself, are involved.

Soil.—This slope between the L'Anguille and the base of the ridge, though in the main heavily wooded, is yet sufficiently well drained to render it the most fertile portion of the county. The soil is a rich, reddish, or yellowish loam, somewhat sandy, while the subsoil is a sort of limonitic hard

pan, which is described more completely elsewhere, and which lies, ordinarily, from two to three feet beneath the surface. Occasionally, however, it may be seen at the surface, and there forms a soil too hard and stiff, to say nothing of its composition, for profitable cultivation. Typical localities where it forms a surface soil may be seen in 5 N., 3 E., section 32, and in 6 N., 3 E., section 18. The subsoil is generally nearer the surface towards the north line of the county than elsewhere. It there approaches to within fifteen or eighteen inches of the general surface.

West of the L'Anguille River the same buckshot subsoil is exposed in every wash, great or small, in the prairie region. In the open and treeless prairies the surface is quite level, save where the lenticular swells before mentioned form a minor topographic feature, while the wooded sections are below the level of the treeless plains. The lenticular undulations so characteristic of the buckshot lands of eastern Arkansas, are seen at their best in these lower forest covered lands. The dryer and more elevated portions of the county form the open prairies while the depressed portions are heavily wooded. So general and so marked is this feature that islets of trees, from one acre to several thousand acres in extent, stand out in bold contrast throughout this section of the county and always indicate an area which is depressed from six to ten feet below the general level of the surrounding country. Where the timber does not occupy these hollows, they are more or less wet and marshy.

The slashes.—In certain townships, notably in 5 and 6 N, 1 and 2 E., these low wet places, or "slashes" as they are locally called, occupy nearly or quite three-sevenths of the whole area. Occasionally they exceed half a mile in diameter, but they are commonly but a few rods in width. In them the limonitic subsoil is reached a few inches below the surface. The lenticular ridges, on the other hand, frequently attain a diameter of from three-fourths to one and a half miles, but they are usually narrow strips, only a few rods in width, though often of great length. Inasmuch as this area is drainable only under the same conditions as would render tillable the alluvial plain of a con-

siderable portion of the White River valley, that is, complete drainage of the White River itself with which this prairie is topographically related, it is improbable that any of the "slash" lands will ever become of value for any other purpose than that of grazing; but for such purpose its value is incalculable. Stretching away for miles, with abundant shade in the numerous tree islets and abundant water in the slashes, these prairies present opportunities for stock raising that are not rivalled by any state in the Union. The vegetation is luxuriant and constant, the grasses generally of exceptional excellence, and few, if any, noxious weeds are to be found, save in the immediate vicinity of the railways, by means of which they have been imported.

Forest encroachment.—The gradual encroachment of the forests upon the prairie region of the county, and in fact of the whole of the eastern portion of the state, cannot escape the attention of even the most casual observer. The advance guard of the encroaching timber is the omnipresent sassafras bush (*Sassafras officinale*) which is everywhere engaged in a war of conquest with the typical prairie vegetation. Scrub oak, box elder, and ash follow close in the wake of the sassafras. The borders of the prairie on every side are distinguished by a close and vigorous growth of this advance guard; unless the skill of man intervene, the Prairie Petite will in a few generations become a reminiscence.

CHAPTER XIX.

THE GEOLOGY OF ST. FRANCIS COUNTY.

The general geologic characters of St. Francis county may be gathered from the pages preceeding in which the general features of the region from Helena to the Missouri line have been given. It is necessary to present here only the sections studied within the county, and then only such as will serve to show the relation between the geology and the agricultural resources of the county. The reader who wishes to gather a general acquaintance with the special geologic problems which the county presents should consult the chapter which treats of those problems in other portions of the area surveyed.

With a single exception all the sections of which the details are given below, are natural ones, and were studied at points where they are best exposed in the deepest cuts and ravines throughout Crowley's Ridge, and in the vertical exposures of twenty feet or more on the east face of the ridge adjacent to Crow Creek and St. Francis River. These exposures are so generally distributed about the ridge, on both slopes, and in its interior, that they surely and completely establish its stratigraphy. Aside from merely local and comparatively unimportant differences the general agreement in lithologic characters of the various sections is worthy of note.

Little Crow Creek section No. I.—A section observed at the head of Little Crow Creek and along its course to a point near Madison, a distance of three and a half miles, shows the following sequence of its members. The section begins south of the Memphis and Little Rock railway, in township 5 N., 3 E., section 35, southeast quarter of the southeast quarter. It is here a cross section of a north and south spur in the heart of the main ridge, beginning just east of the great railway cut at Forrest City.

LITTLE CROW CREEK SECTION NO. I.

(See Plate I., Figure I.)

Bed.	Ft.		Total.
1.	2.	Light colored, thin siliceous humus supporting a strong growth of forest trees	2
2.	15.	Compact, jointed or fissured loess, weathering into vertical cliffs	17
3.	3.	Loess-like, hard, tough, jointed reddish, and somewhat sandy clay. Probably but a local modification of the preceding member	20
4.	10.	Light colored, little sandy, jointed loess, with joints filled with a darker and tougher clay, the whole exfoliating in large slab-like pieces. This member is irregularly stratified and weathers bluish or purplish	30
5.	8.	Reddish, irregularly disposed, indurated clay, reddish above, often thinning out to two or three	

feet........ 38

6. 7. Imperfectly indurated mottled clays and sands, very fine; colors ranging through blue, yellow, and red, the last predominating. At the beginning of this member, along the zone of junction with the preceding, issue springs, and this line marks a spring zone as a rule throughout the ridge. The clays are further characterized by the presence of a considerable quantity of clay limonite in scattered nodules....................... 45

7. 5. Irregularly stratified siliceous gravels, with some purple quartzite. As at many places throughout the ridge, it is here imperfectly cemented into a conglomerate. This member contains occasional pockets of the white quartzose pebbles intermixed with quantities of white or vitreous sand. The pebbles are well waterworn and rounded, while the sand is likewise rounded and coarse. The gravels are often bleached, and are composed chiefly of chert, vitreous quartz, and hard white sandstone. The cementing matter is iron, with which is always associated a trace of manganese. The pebbles of this chert layer are fossiliferous, containing abundant crinoid stems and occasional fragments of *Productus*. Two or three forms of fossil coral were also found here. Much of the gravel is of Carboniferous origin... 50

8. 3. Blue-black and light blue clays, stratified, the strata separated by exceedingly thin partings of glauconite with fine sand, and very great quantities of white mica scales. This association of mica and glauconite is a constant feature at this horizon throughout the ridge in St. Francis county.. 53

9. 10. Blue, laminated regularly stratified clays, with very little or no glauconite................................ 63

10. 2. Cross-bedded, clayey, somewhat indurated, party-

colored sands. (See remarks at the end of the section) 65

11. 1. Cross-bedded, party-colored, and somewhat indurated sands 66

12. 5. Dark blue, carbonaceous, stratified clays, almost lignitic 71

13. 5. Shell marl—(*Ostrea* bed). This is an immense deposit of fragmentary oyster shells, commingled with some blue clay, very hard in places but soon crumbling to a fine powder on exposure to the atmosphere. Additional fossils are *Mytilus hamatoides* sp. nov. and *Natica magno-umbilicata.* The abundant *Ostrea* is probably *Ostrea sellæformis* 76

14. 1. Blue black, nonfossiliferous, glauconitic and micaceous clay, dipping north at an angle of ten degrees 77

15. 5. Glauconite (?) sands, with fine clay partings; contains abundant fossils, among them are *Venericardia planicostata, Turritella carinata, Pseudoliva vetusta, Voluta sayana, Cytherea muttalli, Corbula oniscus,* and *Dentalium turritum* (?) The full thickness of this stratum cannot be ascertained for it passes below the water level of Little Crow Creek 82

This section presents a single abnormal feature to which attention should be directed. It is quite evident that bed number 10 belongs to the division numbered 7 in this section, and that is its usual position in all other portions of the ridge where it occurs. As is indicated above this sequence of strata is founded upon a continuous section more than three miles in length, through a region of great erosion, and abounding in evidences of land-slides of great magnitude both ancient and modern. That it is here placed between two layers of blue clay of the same geologic age is doubtless due to some such catastrophe. These party-colored sands are generally associated with

the gravel beds but are often below them in normal stratigraphic position.

Little Crow Creek section No. II.—In further corroboration of the hypothesis that this general section may be taken as typical for the stratigraphy of the southern half of Crowley's Ridge and for the whole of the ridge in St. Francis county, is the interesting section exposed on this same stream, Little Crow Creek, in township 5 N., 3 E., section 36. On that section the lowest of the members of the preceding section is based, save in point of thickness. The section just presented is built up from a number of smaller sections at different levels above Little Crow Creek in order that a complete cross-section should be obtained, if possible, and was practically completed before the exposure on Little Crow Creek was discovered. The Little Crow Creek section presents a vertical face of about one hundred and twenty feet, and is one of the best to be seen in eastern Arkansas within the Tertiary area. The sequence is complete from the Pleistocene down into the Eocene Tertiary.

LITTLE CROW CREEK SECTION NO. II.

Bed.	Ft.		Total.
1.	4.	Light colored sandy humus	4
2.	40.	Loess, light yellow in color, splitting off in great masses, weathering into vertical cliffs	44
3.	30.	Light colored loess, containing a considerable amount of sand. This represents the character of the deposition of early loess. Reddish below through the oxidation of iron	74
4.	6.	Party-colored, cross-bedded soft sands with coarse and rounded grains	80
5.	5.	Fine gravels, irregularly stratified, the bed consisting of chert, quartzite, and sandstone pebbles commingled with sand; contains frequent pockets of pure white and coarse sand	85
6.	2.	Light yellowish, somewhat carbonaceous clays	87
7.	4.	Bluish or blackish stiff jointed clays, with crystals of selenite. Its juncture with the preceding	

member forms a zone of springs, not only at this point but at numerous places on the east side of the ridge.. 91

8. 15. *Ostrea* bed, made up of fragments of *Ostrea sellæformis*. This stratum is broken into three layers by two blue clay partings, the upper of which is six and the lower fifteen inches in thickness. It is, however, mainly a great mass of *Ostrea* shells, which are usually much comminuted (though entire specimens of from 8 to 12 inches in length were secured) with a matrix of blue clay.* Near the middle of the exposure this bed thickens into a very considerable pocket of shell marl.. 106

9. 2. Compact, stiff, blue clay.................................. 108

10. 5. Horizontally stratified blue clay with thin partings of glauconitic fine sands, with abundant but scattered fossils identical with those given in the preceding section. Near the middle of the section this member thins out and the depression thus caused is filled by the *Ostrea* bed above mentioned, as a pocket............................... 113

11. 3. Blue sandy clay, stratified, the strata separated by thin layers of glauconite with abundant mica scales. Passes beneath the surface of the water. 116

The *Ostrea* bed is divisible, on a color basis, into two portions, the upper or red *Ostrea* bed being much discolored by iron oxide. The lower is blue after the material which serves as a matrix for the fossils. The whole series, from the clay member above the *Ostrea* bed to the bottom of the section dips north, at an angle of ten degrees.

Local dips.—One mile north of the section just given the upper *Ostrea* bed again outcrops in the bottom of Big Crow Creek, and it here forms a considerable portion of the bed of

* Upon many of the shells and intermingled with a mass of them were found attached large numbers of a *Mytilus*, for which, from its close resemblance to the form common on the recent *Ostrea virginiana* of the eastern coasts, the name of *Mytilus hamatoides* is proposed.

the stream. Its distance from the Little Crow Creek section indicates that the dip shown by the latter is locally greater than is common for the Eocene. Indeed, but little value can be placed on any recorded dip in the Tertiary area, for all or nearly all of them are purely local, and many of the places where dips have been observed evidently having been disturbed by land-slides induced by the extensive lateral erosion to which this entire region has been subjected. Nearly all the dips seen may be explained by this or by similar hypotheses.

Lignites.—In the blue Eocene clays, which here and everywhere overlie the *Ostrea* bed when the latter is present, lignite occurs abundantly in small pieces. No masses of any size have been found in this locality, most of the specimens found being no larger than one's hand. Some of these lignites have been studied by Prof. F. H. Knowlton of the U. S. Geological Survey, and his results are incorporated in the main body of this report in connection with the lignite beds of the Tertiary at points further to the north. (See Chapter XXVI.)

Little Crow Creek section No. III.—A section on the north side of Little Crow Creek (5 N., 3 E., section 35, southeast quarter of the northwest quarter), exhibits fifty feet of strata near the heart of the ridge. The exposure is made by the erosion into the cliffs of this rather small stream. It has cut away the Tertiary clays to near the top of the clay member which overlies the *Ostrea* bed farther down the stream.

LITTLE CROW CREEK SECTION NO. III.

(North side of Little Crow Creek, 5 N., 3 E., section 35, southeast of the northwest).

Bed.	Ft.		Total.
1.	2.	Bleached, sandy humus	2
2.	15.	Loess	17
3.	12.	Party-colored, cross-bedded, stratified sands, becoming somewhat indurated on exposure	29
4.	4.	Fine cherty gravel, irregularly disposed, but horzontal in the main, with pockets of sand. Contains considerable clayey limonite in small irregular nodules	33

5. 5. Horizontally stratified clays with thin partings of sand which contain glauconite and mica. Below the clay is without sands, and is much jointed.. 38

6. 10. Fine grained, cross-bedded sands, in layers of varying thickness, red, white, yellowish and purplish in color. This stratum contains occasional thin bands of black or purplish clay. Two feet below the upper limit is a lignitic clay of two or three inches in thickness. This portion of the main layer or stratum consists of very many thin laminæ, separated by partings of very fine white sand. The lowermost four feet contains no clay and the sand is somewhat coarser............... ... 48

7. 8. Fine, compact, blue clay, dipping west 5° north. The lower limit is not exposed................... ... 56

A few yards down the stream from the above section in the blue clay of number five of this section there are numerous large pockets of sand, and large pieces of lignite are scattered without order throughout its lower half. At this point the clay thickens into a pocket and presents every appearance of having been disturbed. It here appears below number six and is probably the more eroded portion of a recent land-slide.

Section at Madison.—As has been stated, Big Crow Creek flows in a southerly course through the central and widest portion of Crowley's Ridge from near the Cross county line. Near the point where it leaves the ridge, as it bends southeastward to join the St. Francis, it exposes the lower extremity of the east half of the ridge as a narrow but high elevation, the most southern point of which is crossed by the Memphis and Little Rock Railway. The railway company has removed the whole point, for several hundred feet, down to the level of its track. The section exposed in this cut is given below, and is illustrated because of certain peculiar features that still await explanation.

SECTION AT MADISON JUST EAST OF CROW CREEK ON THE LITTLE ROCK AND MEMPHIS RAILWAY.*

(See Plate VI., Figure 2.)

Bed.	Ft.		Total.
1.	2.	Light colored siliceous humus..........................	2
2.	20.	Typical loess, eroding and splitting into vertical cliffs	22
3.	18.	Modified loess, rather more clayey in its composition than the typical member just overlying, containing considerable sand, and weathering into a very tough vertical face..............................	40
4.	1.	Thin layer of stratified reddish sand.................	41
5.	4.	Irregular layer of gravel and sand, thickening sometimes to eight feet. The pebbles are assorted, being coarser as a rule toward the bottom. All these gravels as well as the included rather coarse sands are much discolored with iron oxide, a feature especially marked near the underlying impervious layer of blue clay. Near the eastern extremity of the cut the gravels become thicker and are bleached and cemented by iron oxide. The gravels abound in chert, are much waterworn and rounded. They contain, also, well smoothed and rounded fragments of a very hard coarse grained white sandstone, as well as reddish and purplish quartzite. In the pockets both sand and gravel are black, being superficially discolored with manganiferous iron oxide. The gravel occasionally contains a boulder a foot or more in diameter............	45
6.	2–12.	Bluish or black, stiff fissured, and stratified clay, dipping west at an angle of ten degrees. This layer presents an anomaly by greatly thickening toward the east end of the cut. It there	

* The irregularity of the beds exposed in this section lead one to expect that the further excavation of this bank may display sections that vary considerably from the one here given.

becomes nearly twelve feet thick, and abruptly ends by abutting against party-colored cross-bedded sands. Two hundred feet west of the pocket the clay abruptly ends. The thickness averages six feet.. 51

7. 12. Cross-bedded, indurated, party-colored sands, varying from half a foot to four feet. This is exhibited as a sharp wedge entering into the clay layer... 63

It seems probable that the blue clay, no. 6 of the section, represents an ancient channel of erosion in the underlying sands. During the progress of the filling of this channel by the muds which now form the clays, the sands on the west side were swept partially into it and spread out as a fan or bar to be again covered by the continued deposition of mud. Then came those changes which introduced the Orange Sand, so widely distributed throughout the ridge, followed by the changes recorded in the superimposed clays and silt.

Continuation in a well record.—At a point one hundred and fifty feet south of the present excavation at which the above section was made a well has been sunk to the depth of sixty feet. The sands which form bed no. 7 of this section extend downward for a distance of fourteen feet, making in all a total thickness of about 26 feet for this member. Then follow:

Bed. Ft. Total.

8. 10. Bluish or black clays, with very little sand, with which is some glauconite.............................. 87

9. 3. *Ostrea* bed, indicated by numerous fragmentary masses of solidly cemented *Ostrea* shells, in the material around the curb.... 90

10. 30. Sands and clays, glauconitic, fossiliferous, the fragmentary remains being identical with those found in the same member on Little Crow Creek. 120

This well extends the section into the Eocene more than twenty feet further than dces any natural section seen in the county, or indeed, in any portion of the eastern half of the state.

The lowermost portion is the downward continuation of the Crow Creek beds which are a little less than half a mile away.

The Forrest City section.—The Pleistocene members of the Crowley's Ridge series are well exposed in a typical section made by the great railway cut at Forrest City. The locality is about an eighth of a mile east of the depot, and though it is not continuous, it is based on observations which include every part of the cut. The loess is here remarkably well developed and quite characteristic.

THE SECTION IN THE RAILWAY CUT AT FORREST CITY.

(See Plate I., Figure 2.)

Bed.	Ft.		Total.
1.	2–4.	Light colored, siliceous humus	4
2.	30.	Light yellowish loess weathering reddish, the color deeper below, forming vertical faces, which are often much jointed and fissured. Along such fissures the roots of trees penetrate to a great depth. Loess-kindchen or concretions are exceedingly abundant, and as is usual in this region are all solid, and without a nucleus. The western slope of the ridge, throughout the county, is practically composed of this loess eroded and washed over it, though, as thus distributed, it contains considerable limonite, in the form of "buckshot" and some sand	34
3.	1.	Thin layer of bleached gravel, evidently washed from a deposit of Orange Sand near by	35
4.	6.	A friable, not very compact, bluish clay, much jointed and fissured. Toward the bottom it contains an unusually large amount of limonite. This member, itself a modification of some other, passes insensibly into the next lower	41
5.	1–2.	Lighter colored clays, containing an immense number of small nodules of limonite. Near the east end of the cut this layer is divided into two distinct zones, separated by a layer of clay	43

6. 6. Yellowish brown clay, with large soft nodules of limonite. These three members, nos. 4, 5, and 6, are separated almost solely on a color basis and may represent different phases of the same thing 49

7. 8. Whitish or yellowish sands, with fine cherty gravel, often forming pockets. The gravel becomes somewhat coarser downwards, but it is much bleached and has the appearance of having been assorted from a considerable bed of Orange Sand, the coarser material of that formation being wanting. Clay is mixed in pockets with both sands and gravels, the latter being generally stratified. This member is not constant throughout the cut, but disappears further east, where it is replaced by the usual variegated sands, or sands with clay intermixed........................... 57

To the total thickness as here given should be added the further thickness of the loess above the top of the cut which has a thickness of not less than twenty-five feet. This will make the thickness of the Pleistocene at this locality not far from eighty-five feet, of which about sixty feet is of loess. As a rule none of the exposures on the west side of the ridge show more than a foot or two of the clays that underlie the Orange Sands, and if such exposures occur they are usually found in the bottoms of small creeks and ravines. The best exposure near Forrest City is along a small nameless stream about three miles south of the town. The south bank of the stream is precipitous for several hundred feet at the point where it leaves the ridge and the vertical exposure here is quite one hundred feet. After the usual deposits of loess, underlain by gravels with considerable red and white sands intermixed, come the Tertiary clays, here about twenty feet in thickness. They are in every particular the exact equivalents of the beds on Crow Creek.

CHAPTER XX.

THE GEOLOGY OF ST. FRANCIS COUNTY.—*Continued.*

Brick clays.—The brick-yard of Mr. George Cook is in the southern portion of Forrest City. The clays used for brick making at this yard are all surface clays, the loess from the hills mingled with some sand from the Tertiary, and mixed with the humus or top soil. The material is stripped to a depth of from eight to fifteen inches and is lifted carefully from off the clayey subsoil. Under this brick earth is a somewhat sandy clay but it contains also an abundance of limonite nodules. The presence of this mineral impairs the value of the clay for brick-making.

Loess for bricks.—The loess is the best material for brick to be found in St. Francis county. It is the deposit so extensively employed at Memphis and St. Louis and at certain of the more northern cities lying within the loess area. Skill and experience have succeeded in reducing its disadvantages to a minimum in those cities. The chief feature of its successful treatment lies in properly tempering it by long exposure in piles before grinding and moulding. The annual output at Mr. Cook's brick yard is 400,000 bricks, valued at $8.00 per thousand. The bricks are hand made, and the yard does not work regularly.

Features exposed along Spring Creek.—Near George Cook's brick-yard is Spring Creek, a small uncertain stream flowing from the innumerable small springs which issue from the deep and narrow ravines in which the creek heads. Its narrow sinuous bed is filled with the cherty gravel of the Orange Sand derived from a bed *in situ*, far within the small ravines. In the exposures in these ravines the Orange Sand is seen to be identical in constitution, material, and general character with the beds which outcrop on the east side of the ridge, four or five miles away.

Throughout Spring Creek ravine and, indeed, in most localities in the southern half of the ridge which are similarly situated, there is a tough bluish clay or slate-colored, clay-like subsoil, containing a few pebbles above, but abundant gravel

below, which passes suddenly into typical Orange Sand gravels. This clayey gravel layer is, therefore, the counterpart of the one in the Wynne section fifteen miles further north. In Spring Creek the stratum is divided into two members by a layer of sandy gravel or clay, from one to three feet thick, which contains much limonite; the pebbles are small and well rounded, and most of them are well bleached. At several points above the gravel layer, higher up in the hills, is a tough, bluish clay, abounding in soft limonitic nodules and small pieces of lignite. Still further up the stream and thirty or forty feet above the level of Mr. Cook's brick-yard, the gravel and clay layers pass over the underlying sand layers which are well exposed in the railway cut in the east margin of the town. It is, therefore, quite evident that none of the surface soils of the west side of the ridge represent a soil derived from the materials of the ridge with the usual modifications, but that they do represent a series of changes, the complete record of which is lost, a record intimately connected with the period during which the great trough between the ridge and the high lands west of the White River was dug. The topography of the west face of the ridge is of an older type than is that of the east, and its salient features are correspondingly more difficult of interpretation.

The deep well at Forrest City.—Attempts were made to secure the record of the deep well put down at Forrest City, but they were unsuccessful. At the time of the first visit to the region the well was down about three hundred feet, and the boring was being prosecuted at intervals with little progress. No record had been kept by those employed to put down the well, and only the most general information could be gained. The following year the work had been stopped. It is to be regretted that so good an opportunity to know the nature of the deeper strata about the city had been neglected by those to whom a knowledge of that structure was of the greatest importance. If interested parties could recognize the value of such records, both from an economic and geologic standpoint, few wells would go down without a careful and trustworthy record.

So far as could be gathered from conversation with those

who had watched the progress of the work more or less carefully it was learned that the clays of Tertiary age are but a few feet below the surface. A few scattered pebbles were met with but no hard rock of any sort. Lignite was reported at various depths but in only thin beds and possibly it may have been in fragments only. A bed of shells was penetrated, but at a depth not recorded; it was but a few inches in thickness. A few small fragments of shells lying in the debris around the well were recognized as belonging to *Ostrea.* Water was found in a coarse sand. This is the only information that could be gathered concerning the record of this well.

A section on the St. Francis.—A section studied in township 6 N., 4 E., section 29, southeast quarter of the northwest quarter, at a point where the St. Francis River flows directly against the ridge and makes a sharp bend to the south shows the sequence of strata to a height of 155 feet and serves to connect the Copperas Creek section in Cross county with the section on Crow Creek. It is for the most part a vertical section, and, with slight exception, is continuous from the top of the ridge, at its highest point, to the water level below. It marks the site of a gigantic land-slide caused by the St. Francis River.

SECTION ON THE ST. FRANCIS IN 6 N., 4 E., SECTION 29.

Bed.	Ft.		Total.
1.	60.	Loess, nonfossiliferous	60
2.	40.	Sands and Orange Sand gravels, with large masses of chert and some red pipe clay	100
3.	60–70.	Bluish or black stratified Tertiary clays, without fossils other than abundant small pieces of lignite	165

In this section the variegated sands and gravels of the preceding section are massed together, for they are believed to represent the same general class of phenomena and to belong together. The thickness of the gravel member proper is not more than six or eight feet, and is usually somewhat less. Here as elsewhere it is irregularly disposed, often thickening to ten or more feet, and

then almost entirely disappearing, making it an exceedingly variable member of the series.

Conglomerates.—It is a noticeable fact in the section just given that the gravel bed is often conglomerated, a feature common wherever the gravels come close enough to the underlying clay layers to lie in a sort of basin capable of holding the iron charged waters percolating from above. Whenever a conglomerate has been formed of the pebbles, from one end of Crowley's Ridge to the other, the cementing material is an oxide of iron, generally the sesquioxide. Masses of this conglomerate, weighing several tons, lie at the base of the section and close to the margin of the stream. They were traced to their origin in the face of the section about its middle and just above the clay members of the Tertiary series.

The loess.—The loess is the characteristic Pleistocene deposit of Crowley's Ridge and its most remarkable feature. As the reader may have gathered from the foregoing sections this widespread member is to be seen at all points along the ridge in St. Francis county. The crown of the ridge is made up of this soil and, indeed, the greater portion of the uppermost third of the total mass of the hills is composed of it. There is substantial agreement among geologists that the loess deposit is of early Pleistocene age and origin. It is widely spread throughout the interior of the United States, generally along the higher lands that border the larger streams, and it forms a conspicuous element in the surface geology of those states which are touched by the Missouri and Mississippi Rivers, and their tributaries above the Ohio.

In gross structure the loess is a fine, light buff or ashy silt, sometimes presenting well marked stratification and at other times presenting no such evidences. It almost always abounds in a peculiar kind of calcareous nodules called "loess-puppets", "lime-balls" and "loess-kindchen", the latter name having been adopted from the Rhenish name for concretions of a similar character which abound in the loess deposits of the Rhine. The loess is generally a highly calcareous soil, though primarily composed of excessively finely divided material which is largely

derived from siliceous rocks. Under the microscope its grains are seen to be either rarely well rounded and somewhat smoothed or sub-angular, but most of them present sharp or regular angles. It has the general appearance of a silt, is very homogeneous, much too fine to be a sand and too coarse to constitute a typical clay. The soil derived from the loess is usually of great fertility and constitutes some of the richest lands of Iowa, Nebraska, Kansas, Missouri and Kentucky, in which states its area is most extensive. Wherever found it commonly contains land shells, as fossils, usually abundant, and these are sometimes associated with various rare forms of fresh water shells. The occurrence of the loess in any country at once introduces a multiplicity of geologic problems, some of which are of far reaching consequences, and many of which yet await a satisfactory solution.

The thickness of the southern loess.—The loess has been observed along the lower Mississippi to a point several miles below Vicksburg, at and about Memphis, Tennessee, and at a few other localities mainly on the east side of the Mississippi River. At these points all observers agree in giving the loess a thickness which ranges from fifteen to more than eighty feet. The southernmost exposure of this formation studied in Arkansas, is at Helena, where it attains a maximum thickness of nearly ninety feet. At that place it presents all those peculiar features for which it is noted elsewhere.

In St. Francis county, wherever the loess occurs, it is usually as a blanket or mantle covering all other formations which enter into the stratigraphy of Crowley's Ridge. It caps the hills, even the highest of them, and forms the greater part of their upper third. At its base it passes into the sands and gravels of the Orange Sand formation, with which, at certain points, it is often intimately associated, and when commingled with the Orange Sand it often forms the mass of the arable slopes. Loess washes very badly, and as a result the crests and slopes of the ridge are deeply furrowed with narrow ravines. In many localities it is protected against rapid erosion by a very heavy forest growth. At no place in St. Francis county, nor, indeed, in the whole Crowley's Ridge area has the loess been seen in any other strati-

graphic relation than that herein indicated. It has never been seen lying upon the Tertiary clays at any point. Wherever the Orange Sands are absent from any section the loess is also wanting. In the lower portion of the loess there is sometimes an occasional chert pebble, but always in such relation as to make it reasonably sure that they represent disturbed pebbles, that is to say, they are pebbles which are derived from the underlying Orange Sands at the time of the deposition of the loess. Usually the latter formation is much more sandy in the immediate vicinity of these straggling pebbles. They have been noticed only in the lower portion of the loess.

Fossils in the loess.—In St. Francis county the localities at which loess fossils have been found are few indeed. One marked point is on the north road to Madison, where the road descends into the ravine occupied by Spring Creek, a small tributary to Big Crow Creek. Here the road cuts through the loess for a depth of ten feet and fossil shells are abundant. The following forms were found at this place, of which only one is a fresh water form. The remainder are land shells, and most, if not all, of them are now to be found living in the surrounding region.

Stenotrema monodon, Rackett.
Stenotrema hirsuta, Say.
Triodopsis palliata, Say.
Mesodon thyroides, Say.
Succinea obliqua, Say.
Pomatiopsis lapidaria, Say; fresh-water form.
Zonites minusculus, Binney.
Zonites arboreus, Say.
Selenites concava, Say.
Patula alternata, Say.
Conulus fulvus, Say.
Pupilla sp. indt.

Along Spring Creek.—Spring Creek, in the lower part of its course, flows over a bed of well bleached pebbles, mainly of chert, which belong to the Orange Sand series. In a few places only does the stream cut through these gravels to the underlying Tertiary clays. The gravel bed proper, in the lower part of the

course of the creek, is overlain by a gravel bearing blue clay, the pebbles in which are somewhat coarse, and are all well bleached.

The flat land on each side of Spring Creek, as well as that on both sides of Big Crow Creek, of which it is a tributary, is a plauteau of Orange Sand and pebbles, the latter being often cemented into a conglomerate. As seen in section in the banks of these streams the gravel beds are cross-bedded, contain much coarse sand, and are interpolated with irregular layers of sand and clay. Somewhat abundant small and rarely large pieces of silicified wood occur throughout the gravels of both Spring Creek and Big Crow Creek. One piece weighing several hundred pounds was found in the bed of Big Crow Creek. On the same road, but on the east side of the ridge, near the village of Madison, the loess is fossiliferous, with abundant concretions, and evident stratification. Nearly all the shells taken at this point were accidentally crushed so that only the two following could be identified.

Patula perspectiva, Say ;

Pomatiopsis lapidaria, Say, (fresh-water.)

It is quite probable, however, that they would all have been found practically identical with those found at the preceding locality, a mile and a half further west.

Localities of fossiliferous loess.—The fossiliferous exposures of loess are so uncommon in St. Francis county that a particular mention of all places where it so outcrops will be made. Wherever the loess is fossiliferous it appears to have been modified or redeposited, and represents a newer phase of the formation. Near the top of an east spur of the main ridge, one and a half miles north of Madison, fossils occur at an elevation of two hundred and seventy feet above the valley. The fossiliferous portion at this locality seems to be differentiated from the mass of the formation which has oxidized into a reddish and tougher clay, and into which it insensibly graduates. It constitutes a sort of fringing blanket of variable thickness on the body of the loess. While this bed is fossiliferous the loess underlying it is entirely without fossils.

Another very characteristic outcrop is in 4 N., 4 E., in the northeast quarter of the northeast quarter of section 26, also on the east side of the ridge and likewise abounding in loess-kindchen and fossils. At this locality the exposure is nearer the top of the hills than it has been observed elsewhere in St. Francis county, but the ridge is here somewhat lower. From this point to the northern boundary of the county there are numerous localities at which the non-fossiliferous loess occurs but the modified fossiliferous form is not to be seen.

On the western slope of Crowley's Ridge the best marked exposures of loess are about a mile north of Forrest City, in the road leading to the Big Bluff of the St. Francis River. At this point the formation is very deep. It contains no fossils, but it abounds in large, irregular and solid concretions. The bottom of the loess is not exposed though it is much cut up by deep gullies.

South of Forrest City on what is known as the south Madison road, and at a point just east of the Marianna road, is the best exposure of fossiliferous loess on the west side of the ridge in St. Francis county. The fossils occur at an elevation of two hundred and seventy-five feet, and are associated with abundant concretions. The deposit is well stratified. The following are the fossils at this locality:

Mesodon profunda, Say. Common.
Helicodiscus lineatus, Anthony. Common.
Pomatiopsis lapidaria, Say. Abundant. (Fresh-water.)
Pupilla pentadon, Say. Rare.
Cionella subcylindrica, Muller. Rare.
Zonites arboreus, Say. Abundant.

These localities typify the usual modes of occurrence and the main modifications of the loess of St. Francis county, and in the main represent the particular features of the formation throughout the ridge. It is evident that whatever may have been the condition of things at some former period, the modified or newer loess, which is always characterized by being fossiliferous, is now found in patches only. It is always in juxtaposition to undisturbed and unmodified loess, on both slopes of the ridge ,

and often near its very summit, but at a tolerable uniform height which varies from two hundred and fifty feet to two hundred and ninety feet above tide level. The modified loess is always a thin deposit even in its greatest developments.

Lignite.—It would, perhaps, be useless to further multiply sections in such detail, in illustration of the stratigraphy of Crowley's ridge in St. Francis county. However, two additional ones are here presented, the first as furnishing the only section where any considerable deposit of lignite was observed in place, and one which has given rise to fabulous stories concerning the future mining interests of the region; the second to illustrate the only section in the county which positively connects the Eocene of the Arkansas River at White and Red Bluffs, Jefferson county, with the Eocene of St. Francis county. The first of these sections is very near the Lee county line, in 4 N., 4 E., section 26, northeast quarter of the northeast quarter. The locality is in a small ravine, tributary to a still larger one and faces west. Both ravines are tributary to the St. Francis River.

SECTION IN 4 N., 4 E., SECTION 26.

(See Plate VI., Figure I.)

Bed.	Ft.		Total.
1.	2.	Humus, largely modified loess	2
2.	25.	Loess, unmodified, with abundant concretions, and a little unstratified sand	27
3.	8.	Sandy, reddish and variegated clays, becoming slate colored below. Compact, weathering into vertical faces and steep slopes	35
4.	25.	Bluish, tough, jointed stratified clay, with layers of fine sand intercalated	60
5.	2.	Brown, very compact and hard lignite, with some laminæ approaching cannel coal in color, fracture and lustre, but with numerous partings of fine sandy clay	62
6.	3.	Whitish, or slate colored, hard, compact, somewhat sandy, fine and stratified clay	65
7.	30.	Bluish and blackish stratified clays (Eocene). The base of this bed is not exposed	95

The lignite bed seen at this point is about sixty feet above the flood plain of the St. Francis River. It was impossible to determine its distribution over this portion of the county, as no other natural exposure could be found, nor was there an accessible well record to furnish a clue to its distribution. Similar beds are said to exist along the various deep ravines in the northern portion of St. Francis county, but diligent search failed to bring any of them to light. It is the occasional occurrence of this lignite bed in the hills and outcropping in the gullies which has led to the erroneous opinion that good bituminous coal would yet be found in St. Francis county.

Section at Double Head Bluff.—The only other locality to which it is necessary to call attention is at Double Head Bluff on the St. Francis River, in 5 N., 4 E., section 18, northwest quarter of the northwest quarter. The same members which appear along Crow Creek form the upper ninety-five feet from the top of the bluff, and below there is exposed six or eight feet of weathered and hard sandstone. Fossils abound in the heavy talus which its disintegration forms, as well as in the considerable masses which lie detached, but entire, in the bed of the ravine. The sandstone is underlain by blue and black clays and is overlain by heavy beds of a similar Eocene clay. The fossils were carefully compared with those found at Red and White Bluffs in Jefferson county, and with others from Cleveland county, south of the Arkansas River, and found to be identical with them. There is no doubt but that at these widely separated localities the same member of the Claibornian Eocene is exposed.

Silicified wood.—In the same ravine a mass of hard white sandstone, weighing over three hundred pounds, was observed with the cherty gravel of the Orange Sands from far up the sides of the bluff, and associated with numerous small pieces and occasional very large masses of silicified wood. It is a fact worthy of mention that throughout the ridge, in all streams whose beds consist largely of these cherty gravels that there are masses of a similar white sandstone and also similar detached pieces of silicified wood. These fossil woods are of great interest as may be

gathered from the facts set forth by Prof. Knowlton who has studied the material collected in this region. (See Chapter XXVII. of this volume).

This section presents nearly two hundred feet of strata, from the Eocene at the bottom to the modified loess which crowns the whole. The clays have resisted to a considerable extent the erosive action of the river and this causes the extensive Tertiary plateau at this place.

CHAPTER XXI.

THE GEOLOGY OF ST. FRANCIS COUNTY.—*Continued.*

Discussion of the Sections.

The two forms of loess.—The widespread occurrence of the loess throughout the highest portions of the southern half of Crowley's Ridge, as shown by all the sections which include the beds at its summit, and the marked differences presented by what is here called the modified loess, call for some remark. The latter is rather less sandy in places than the typical loess, and can be regarded only as its more modern or newer representative. The typical loess is more nearly a hard-pan than is its modified representative, and contains a considerable quantity of the carbonates, chiefly calcium carbonate, as is shown by chemical analyses. It has nowhere afforded any fossils though the characteristic solid concretions are common to both the typical and the modified forms. The true loess is always rather more indurated, and does not present those distinct evidences of stratification which are so common in the fossiliferous portion, and is, on the other hand, exceedingly homogeneous in its appearance. The unmodified portion forms a stiff soil when worked, and is less fertile than its congener, the fossiliferous loess silt. Both members are of late Pleistocene origin, and are believed by geologists to be of glacial derivation. The two soils have been studied by President T. C. Chamberlin, of the University of Wisconsin and the U. S. Geological Survey, and by Professor Van Hise. As a result of this examination Professor Chamberlin says: "Among the residue,

aside from quartz and kaolinite—not unfrequently iron stained —there were found rare black opaque particles, presumed to be oxide of iron; also a few colorless flakes which may possibly represent a white mica, and a few minute grains of greenish color exhibiting decided pleochroism. These resemble hornblende and they are certainly a complex silicate. However, neither hornblende nor mica were positively identified.

"A large quantity of material properly treated and separated would probably give a sufficient number of grains of these elements to admit of identification; but with the material at hand no possible conclusion more definite than the above can safely be made. It does not seem to me to indicate satisfactorily what was the origin of the silt. A certain small quantity of undecomposed Archæan constituents is to be expected, even if the mass be not of glacial origin, while on the other, if glacial, its distance from the ice might render the presence of coarse mechanically formed particles comparatively rare."

That this southern loess should be rather finer than that of the north is to be expected, for the fine silt particles of the loess would remain in suspension longer than the coarser ones. The relation of the unmodified loess to the fossiliferous and lighter loess silt seems to indicate that the later form, being much finer in texture, has been derived from the former and was deposited in shallower water. It always appears as a fringing sheet or rim over the true loess, and is for the most part now being rapidly eroded away.

The origin of the underlying bluish and reddish clays is intimately connected with that of the loess silts and must possibly be considered in connection with them. They are equally fine, are often stratified, and have been in these sections, differentiated almost solely on a color basis. Their color is certainly an acquired one, due to oxidation.

The gravels.—The gravels are unique and easily recognized. Their rude stratification, want of assortment, and the contained sand pockets, the sands of which range through various colors from white to brown or even red, their considerable thickness in some localities and comparative thinness in others, all appear

to indicate a rapidly formed deposit. That their presence and arrangement are due to great floods, as some have supposed, does not seem clear. There is no law of distribution in respect either to the kind of material or its fineness. Associated with the most abundant small chert pebbles are often found large masses of the same material several hundred pounds in weight and great masses, sometimes angular, sometimes rounded, of a very hard white quartzite derived from the Tertiary region farther to the north. No reasonable explanation of the occurrence of these last named masses has yet been made which will account for all the peculiarities of their distribution. But they occur only in the gravels or in such relations as to necessitate their reference to the gravels as a source of secondary origin. Again, the large masses of chert often contain fragments or casts of Carboniferous fossils, and since most of the chert appears to be similar to that found in the Carboniferous regions of Kentucky and of northern central Arkansas and southeastern Missouri it seems highly probable that these Carboniferous strata were their source. Mingled with these gravels are many large pebbles and more abundant small ones, of a hard, fine grained, white sandstone evidently derived from the extensive beds of Tertiary quartzite in the counties further to the north. (See pages 90 to 100.) It is quite probable that these extensive quartzite beds are the source of a very large proportion of the sands of the region and particularly of those immense beds associated with the gravel deposits. The sandstone fragments often attain dimensions of several cubic feet and many hundreds of pounds in weight. In every particular they are the exact counterparts of the immense deposits found on the west side of the ridge in Craighead and Greene counties, even to the degrees of change of coloration induced by oxidation. The sole problem that they present is that of method of transportation.

General stratigraphy.—Leaving out local details, the stratigraphy of Crowley's Ridge in St. Francis county, beginning with the latest or newest beds, is as follows:

I. A modified loess, with enough sand to render it

decidedly siliceous. This is the surface member and is usually of but little depth.

II. Typical loess, of a depth which varies from thirty to ninety feet, eroding badly and capping the ridge even at its highest points.

III. A clayey, pebble-bearing, bluish or otherwise dark colored loess clay which forms the base of the typical loess deposits, and possibly marks the first stage of the loess deposition. This member is of a variable thickness, and is not always present. The pebbles are most abundant in its lower portion.

IV. Party-colored, cross-bedded sands, of considerable difference in degrees of fineness, often quite regularly stratified, often overlying the pebble bed of the foregoing sections, though these sands usually occur beneath the pebbles. The sand grains are well rounded, and the whole has an occasional mass or pocket of red, white, drab, or yellow pipe clay.

V. Pebble beds as described above, of irregular thickness, usually rudely stratified and sometimes well assorted, with pockets of sand or of clay derived from the underlying Tertiary clays.

VI. Blue, black or drab horizontally stratified clays, with small and sometimes rather large pieces of lignite, all coniferous so far as yet studied, and all of Eocene Tertiary age. This member forms the mass of the southern half of the ridge. It is to be seen only in the deepest ravines on the margin, or along the St. Francis River and such of its tributaries as flow from the ridge. It is occasionally penetrated in deep wells, as at Forrest City, and is thus seen to be the underlying stratum in the whole region. The lower portion of this member is fossiliferous and the fossils are Claibornian.

Resume.—The Tertiary portion of the geologic history of St. Francis county represents a former extensive plateau, the western limit of which was the paleozoic scarp of middle Arkansas, that lies just west of the St. Louis, Iron Moun-

tain and Southern Railway, and noted in the introduction to this report. This plateau was removed by the waters which are now represented by the White River and other streams, to which, near the northern boundary of the state, the Mississippi added enormous volumes of water, either continuously or periodically. The whole of the country between Crowley's Ridge and the paleozoic rocks on the west was thus lowered and carried away, save where a few unimportant secondary ridges, such as that at Augusta, in Woodruff county, remain to bear witness to the former height of the whole country. East of Crowley's Ridge the Mississippi has ploughed out an immense trough of which the present Mississippi bed is but a small part. But while the river dug its former bed wider it also dug it deeper. It encroached upon the Tertiary clays to the west, the limit of which deeper encroachment is marked by the present trough of the St. Francis River. Since the recession of the Mississippi River to the east there has occurred a process of refilling which, though continued for ages, has not yet brought the level of the channel east of Crowley's Ridge up to that of the one on the west of the ridge. During the process of denudation the whole southern basin of the Mississippi was slowly sinking, the Gulf traveled northwards, and the site of Crowley's Ridge became a shallow area, with possibly occasional strips of sandstone in the northern portion, as narrow islands, or even as a chain of islets along the margin of which came slowly flowing the silt laden waters of the north, and these deposited their burdens as the loess and related formations which now make the greater part of the upper half of the ridge. Then came an elevation and the whole region again became dry land, the work of erosion again began, and the rivers, creeks and brooks, aided by wind, frost and rain, have gone on completing the work of destruction—the removal of Crowley's Ridge. These forces are now in operation and the work of denudation is still going on. Geologically all this work, from the deposition of the pebble beds upwards, but not including them, has been done in Pleistocene times.

CHAPTER XXII.

THE GEOLOGY OF ST. FRANCIS COUNTY.—*Concluded.*

Soils, Marls, and Lignites.

Soils of the bottoms.—The surface soils of the county are roughly divisible into two groups, each of which maintains well its characters wherever seen. Both are products of the erosion of the mass of Crowley's Ridge, the lithologic peculiarities of which are reflected in the soils derived from it. To the east of the ridge and in the valley of the L'Anguille River the surface soil is a kind of black loam more or less rich from the presence of organic matter, such a soil, in fact, as is usually to be found on lands subject to periodical overflows. This class of soils constitutes our first group. The arable soils of the St. Francis–Mississippi bottoms are deeper and richer than the soils of any other part of St. Francis county, but they are limited to comparatively small ridge like areas. In the L'Anguille bottom the area of black loamy soil is not only small but its depth is but slight, rarely exceeding a few inches, though it occasionally attains a thickness of two or three feet. This class constitutes the best land in the county, and it is usually very productive. Its value, however, is somewhat diminished by the fact that it is underlain by a limonitic clay or hard-pan, or buckshot subsoil, a feature especially noticeable west of Crowley's Ridge, where, in many places, it comes to the very surface. The lands so underlain are heavy or sour from defective drainage. They produce, with careful cultivation, from one half to three fourths of a bale of cotton to the acre, and usually yield excellent crops of corn and oats.

The soils of Crowley's Ridge.—The soils of Crowley's Ridge form the second group. They are best described as siliceous soils, which wash badly, light in color, reddish and yellowish predominating, and in some localities are stiff with abundant clay. It is an interesting fact that the loess soils of the south portion of the Mississippi valley do not

maintain the reputation of that formation for productiveness, and the ridge soils do not seem to have been regarded by the planter with much favor. Aside from this it is to be noted that wherever the grasses and other forms of vegetation have been removed from the slopes of the ridge large gullies are formed in a short time which soon become extensive ravines or even deep canyon-like embayments. It does not take long therefore for the soils to be removed to a depth beyond which their fertility is questionable. Nevertheless, there are sections where the top of the ridge is sufficiently flat to make tillage possible, and at such places the soil yields a fair return. All the ridge soils are liable to speedy exhaustion, a condition hastened by the generally prevalent method of farming, which, it is scarcely needful to say, is a method which does not contemplate rotation of crops as one of its leading principles. There are certain crops, however, to which these ridge soils are especially well suited, and in producing which they never fail. Among them are both sweet and white potatoes, of which, however, there are grown sufficient only for home or local consumption. Clover does well, for two or three years after seeding. Millet yields very large returns and ought to be more extensively grown. It seems quite clear that careful and judicious planting, with rotation of crops and a gradual transition from the prevailing cotton growing to general husbandry, in which the needs of southern cities and the desire of the northern ones for early fruits and vegetables are considered, would prove of invaluable service to both land and owners.

Soils of the slopes.—To the third group of soils belong all those lands which lie along the slopes of the ridge, on both sides, the western of which in this county, are by far the most extensive. These soils are the products of erosion of the soft materials of the adjacent hills, and are largely composed of loess mingled with sands and clays from the deeper strata of the ridge. Occasionally there are to be found some pebbles derived from the generally distributed gravel bed.

but they are rare, especially on the west side of the ridge. These slopes form the best farming lands in the region, one marked feature which adds to their value being an almost perfect subsoil drainage. They are, however, as the analyses may indicate, generally deficient in lime which could be profitably used as a top dressing, and may be cheaply supplied from the extensive beds of calcareous shell-marl along Crow Creek. It is further true that these marls would add to the soils other desirable materials though their value must be settled by experimentation rather than by any estimation based on their chemistry.

The value of analyses.—The accompanying tables of analyses are designed to express the comparative values of the soils and marls of St. Francis county so far as the chemical analyis can show them. It might be well here to guard against a very common impression that a chemical analysis represents a final verdict upon the value of a soil for farming purposes. Soils are very complex, the greater part of the elements entering into their constitution being in very small quantities, and their fertility being dependent largely on the rate and completeness of the decomposition to which its mineral elements are subject. That is to say the availability of the constituents is quite as important a matter as their presence. Only the presence of these constituents can be determined by chemical analysis. Such analysis, therefore, can decide upon the agricultural value of a soil only within certain limits. It may determine the absence of some important mineral element, or the presence of some element deleterious to plant growth; in either case it renders an important service to successful tillage. But the ultimate question, "is this or that soil fertile?" can be decided best by careful experimentation, even when analysis has shown the presence of desirable elements.

Marls.—The marls present another problem in the chemistry of the farm. They may serve as a compost, that is, as an addition to the soil, to add to it desirable elements as plant food, or they may serve as a top dressing, that is, as substances

whose presence or whose own chemical activity aids in making available desirable elements already present in the soil but which exist in undesirable or useless combination. Here, too, experimentation must come to the chemist's aid. There may be used too much or too little of the supposed valuable marl and in either case there will result failure to reach a satisfactory conclusion except as trials and observations are carefully made. In no case has this been done with any marl from St. Francis county. The question of their value will never be settled until some public spirited man shall conduct personally, or by proxy, continued and careful practical experiments with them.

Considered from a purely commercial standpoint neither the Crowley's Ridge nor the Beebe marls, the analysis of which is introduced here for purposes of comparison, presents those peculiar elements of value which are recognized as being present in the marls of New Jersey and the Carolinas, but there can be no doubt but that they will prove of far greater practical utility than many of the high priced artificial fertilizers. These analyses, then show little more than that to soils deficient in lime, as much of the ridge soil and the prairie soil undoubtedly is, these marls will probably prove of value as a top dressing.

The only information accessible connected with the actual use of these marls is given here. The late Col. Paul M. Cobb states that about 1875 a wagon load of the Crow Creek marl was put on a garden at Forrest City "and it burned everything up."

Judge Thomas Pearce and Captain W. H. Pearce, of Goodwin, used some of this marl, about the same time, "and the good results are apparent yet." Here are two expressions of opinion diametrically opposed to each other, a difference probably due to the methods of application. In this connection Judge Pearce says that one hundred bushels to the acre will make the prairie soil in the neighborhood of Goodwin "about right." In any attempt to use these marls it should be remembered that while lime is a useful fertilizer on some soils, it does not follow that "the more the better."

Analyses of St. Francis County Soils.

LOCALITY.	Silica and insolubles.	Iron (ferric) oxide.	Alumina.	Lime.	Magnesia.	Potash.	Soda.	Manganese.	Phosphoric acid.	Loss on ignition (include carbonic acid.)	Total.	Water at 115 C.	REMARKS.
Crowley's Ridge	76.30	16.86		1.00	1.22	.54	.89	....	trace.	2.83	99.64	3.82	Modified loess.
Little Crow Creek	82.13	11.68		.02	.49	.69	.45	....	trace.	4.60	100.06	3.51	
Goodwin Station	75.26	5.60	11.90	.50	.82	1.04	.72	trace.	trace.	5.02	100.86	3.74	Prairie soil.
North margin Goodwin prairie	82.52	4.32	7.50	trace.	.40	.52	.63	trace.	trace.	4.45	100.84	7.82	Subsoil 30 inches below surface.
Prairie	81.62	2.94	7.60	1.15	.41	1.28	.64	trace.	trace.	3.64	99.28	2.11	Cultivated field.
Goodwin prairie hard-pan	84.04	3.70	6.32	.34	trace.	.91	.80	trace.	....	3.32	99.43	1.40	

Marls.

LOCALITY.	Silica and insolubles.	Iron (ferric) oxide.	Alumina.	Lime.	Magnesia.	Potash.	Soda.	Manganese.	Phosphoric acid.	Loss on ignition (include carbonic acid.)	Total.	Water at 115 C.	REMARKS.
Shaft at Beebe, White county	73.26	10.02		5.45	1.05	.70	.78	....	trace.	10.59	101.80	4.74	Shell marl.
Crow Creek, St. Francis county	35.84	10.23		26.56	.68	.18	.66	....	trace.	25.51	99.66	1.96	
White Bluff, Jefferson county	73.67	12.90		2.42	.59	.55	.63	....	trace.	8.72	99.48	3.86	

The following specimens were collected by Hon. Wm. Manning, of Goodwin, St. Francis county.

Partial Analyses of Soils.

LOCALITY.	Potash.	Soda.	Phosphoric acid.	Nitrogen.	Total.	Water at 115 C.	REMARKS.
4 N., 1 W., Sec. 3, S. E. ¼..	.63	.91	.17	.43	2.14	2.27	Prairie soil.
	.61	.72	.19	.43	1.95	3.16	Surface soil in timber.
	.64	.84	.14	......	1.62	2.66	Prairie subsoil.
	.87	1.32	.11	......	2.80	4.82	Sterile. In timber.
	.50	.61	.08	......	1.19	3.44	Fertile. In timber.

Deductions.—Of the marls given in the foregoing table that from the Tertiary of Little Crow Creek possesses the greatest value as a fertilizer.

With respect to the agricultural value of the soils the table shows that the bottom soil or hard-pan of the Goodwin prairie to be least suited to successful tillage. Its retentiveness of moisture is least, its percentage of insoluble silicates and other insoluble matters greatest. The surface soil of the Goodwin prairie is, so far as analysis can testify, the best soil, that is, it is the most lasting. The considerable percentage of water retained by its subsoil is readily accounted for by the presence of the impervious limonitic hard-pan, with which it is generally underlain. The prairie soil is thin and the whole country flat. Water will remain for long periods at a time on the surface of this prairie region and thus render the lands cold and wet.

Generally, then, it may be said that most of the arable soils of St. Francis county contain plant food in fair quantity and in a tolerably soluble condition. Their chief deficiency is in lime and available phosphoric acid. The ridge soils are easily tilled and thrifty when new, but possess little durability. For the future, as now, the best farming lands will be those that lie along the gentle slopes at the foot of Crowley's Ridge, on either side, and extending well out toward the L'Anguille on the west.

In this brief estimate the rich alluvium of the overflowed

regions is not considered, for, from the presence of abundant decomposing and decomposed organic matter, as well as from the constant addition of silt or soil from other regions, this quality of land is always fertile and easily tilled.

Minerals.—From the general geology of the country, as seen in the various detailed sections, it may be readily gathered that there are no economic products of a geologic character to be found within its limits. There are neither ores nor coals. The lignite is not available for fuel, first, because it is a rather poor variety of brown lignite, and, second, because its relation to overlying and underlying soft clays are such as to render its mining expensive and difficult. It also contains numerous partings of clay.

The chief wealth of St. Francis county consists in its agricultural resources and its timber. These resources will increase with that skill in farming and care of tillable lands which are imperative if these soils are to continue remunerative to culture. The mere abandonment for a term of years of a field on which cotton has been grown for two generations will not, alone, render it again serviceable for this crop. Attention to the conditions which make other crops successful, coupled with their systematic rotation, will be essential. It does not seem to be quite within Nature's scheme that, when land is already exhausted by one or two decades of the same crop, it can be further forced to yield elements which it no longer contains.

ST. FRANCIS COUNTY; RECAPITULATION.

It is believed that the facts gathered in this survey of St. Francis county will warrant the following general summary:

Geologic.—1. The oldest strata exhibited in the county belong to the Eocene Tertiary, and are of Claibornian age.

2. The pebble beds are to be connected with the Orange Sands, are of later deposition, but both are Tertiary.

3. A clearly drawn line, between the Pleistocene and the Tertiary is, in this county, in the present state of our knowledge, impossible.

4. The loess that caps and skirts Crowley's Ridge belongs to the earlier stages of the Pleistocene.

Economic.—1. No ores of value occur in St. Francis county.

2. The marls of Crow Creek will possess, until careful experimentation, only a hypothetic value.

3. The beds of lignite have no present or prospective value.

4. The character and composition of the soils are such that rotation of crops is essential to their continued fertility.

5. The character of the natural forests now growing in the county is such that judicious lumbering will retain the forest areas as remunerative resources. The forests also suggest that fruit growing may prove a profitable industry.

6. The future wealth of the county, as well as its prosperity, lies in its agricultural and possibly manufacturing resources.

CHAPTER XXIII.

NOTES ON THE FOREST TREES OF THE CROWLEY'S RIDGE REGION.

The sources of information concerning the forests of the region included in this report have been of a threefold nature. First, there has been as careful noting of the various trees, together with abundance, distribution, and similar data, as was possible with one whose chief concern was with the geology. The notes on forrestry, therefore, must be regarded in the light of fragmentary studies of such districts as were particularly noticeable. Added to this information is that gleaned from the lists of Prof. Leo Lesquereaux,* Prof. F. L. Harvey,† and the Report in Volume IX. of the Tenth Census of the United States.§ Many forms were noticed which were not recognized; the list is, therefore, necessarily incomplete. In the following pages such forms as were not personally noted and listed, but

* Second Report of a Geological Reconnoissance of Arkansas, by David Dale Owen, 1860 Botanical Report, pp. 320-399.

† The Forest Trees of Arkansas. Reprint from the American Journal of Forestry for June and July, 1883.

§ Forest Trees of North America. By Professor C. S. Sargent.

which are given on the authority of one or another of the authors above cited are indicated by an asterisk.* The List of the Plants of Arkansas, published in Vol. IV. of the Geological Survey's Report for 1888 is followed for order of arrangement.

A few words in the way of general introduction may be allowed. In the first place there is a great similarity in the forests in the lowland region east and west of Crowley's Ridge. This similarity extends both to the species and their abundance. But the physical differences are not great and little else is to be expected. However, there are some minor facts of interest in the distribution of certain species. Cottonwood, for instance, is far more common in the valley of the St. Francis than in that of the L'Anguille. Beech is more abundant along the northern third of the ridge country than farther to the south. The pine areas are very much restricted on the ridge, and are found only on those parts of it which are surmounted with sands and gravels; in other words, only where the Tertiary sands and gravels rise quite to the tops of the hills. It does not, as a rule, run far down the sides of the hills and is rarely found in the valleys. The cypress is abundant alike in the lowlands on both sides of the ridge, but it is seen at its best in the valley of the White River. The poplar does not appear to any extent at the tops of the hills, and where they are sandy it is never found; but in the valleys it is both abundant and large.

In the second place the forests are often very dense and the timber of a superior class. In many sections of this region the forests are still practically untouched and stand in all their original vigor. While certain modifications need to be understood for this statement concerning those localities which are along the railroads, it is quite true for the mass of the forest covered region, that is to say, for all eastern Arkansas except the small areas of prairie lands in the valley of the White River. It is true, also, that the habits of stock which seek mast are slowly modifying the nature of the forests by changing the nature of the undergrowths. Some they trample quite out of existence, other forms they seriously affect so that they are engaged in an uncertain struggle for existence. The oaks bearing bitter fruits

are on the increase while those whose fruit is sweet are on the decline in respect to the number of young trees growing in stock raising districts. The result is easy of interpretation. The newer forests will eventually be composed largely of the black oaks and similar forms with bitter mast.

A third feature of great interest lies in the encroachment of the forest areas on the few remaining prairies of eastern Arkansas. Few large prairies now remain, and the largest of these is the region west of and near DeVall's Bluff, that is, west of the White River. About all these prairies are to be seen the advance guard of the forests, pushing their way into the treeless region in long straggling outliers of black jack, sassafras, willow oak and blue ash. Mixed with them are a goodly number of sumach bushes of all sizes, and these all are reclaiming the lands to the forests.

The railways are modifying the character of the herbaceous vegetation to a marked degree all along their course. Many northern and western plants, seen nowhere else in eastern Arkansas, were noticed along the Iron Mountain railway. Some of the more common noxious weeds are being rapidly introduced. Many of the prairie regions, the source of most of the native hay of the eastern part of the state, are being claimed by these strangers. About Goodwin and through the Grand Prairie this encroachment of imported weeds is very marked.

Such further notes as may be of general interest may be found in connection with the several species mentioned in the subjoined list.

REGISTER.

THE MAGNOLIA—(*Magnolia grandiflora*, Linnæus.)

This species has not been observed outside of gardens and yards, and then it was not noticed as attaining its maximum development. Inquiry revealed the fact that the ornamental trees were derived from shoots or slips, and that failure invariably followed attempts to grow the tree from the seed. Numerous fine examples may be seen in gardens in Wittsburg, Forrest

City, Marianna and Helena. It is, so far as could be learned, not indigenous to this portion of Arkansas.

THE CUCUMBER TREE—(*Magnolia acuminata*, Linnæus.)

The "cucumber tree" is abundant throughout Crowley's Ridge on either slope, where it attains magnificent proportions It is very common about Forrest City and south of there. The wood of this tree is said to be excellent for interior finishing.

MAGNOLIA—(*Magnolia macrophylla*, Michaux.)

On Hilton Creek, three miles south of Forrest City, are three specimens of a magnolia with very broad leaves which are referred to this species. If the reference be correct it is fair to presume that other specimens exist in the region, though none were seen.

THE YELLOW POPLAR OR TULIP.—(*Liriodendron tulipifera*, Linnæus.)

The tulip tree abounds in the valleys of the Cache, the White, the L'Anguille and the St. Francis Rivers. It rarely reaches far up the sides of the ridge, being confined to the slopes or immediate bottoms. It is deservedly popular at home and abroad, and is much sought after and marketed under the name of poplar. It is rather more abundant in the northern half of the ridge, and though the forests there have been twice cut over, and the largest and best of this valuable form have been removed, large quantities are still standing. In the valley of the St. Francis, east of Harrisburg, immense trees and in large numbers are still to be found. The same is true of the Cache valley west of Boydsville, Gainesville and the regions south, removed from the railways. This tree belongs to the natural group which includes the magnolias.

THE PAW-PAW—(*Asimina triloba*, Dunal.)

The paw-paw is one of the most abundant trees in the lower lands along the Cache, White and L'Anguille Rivers. It is common on the St. Francis; but it is far more common to the north in the regions about Crowley's Ridge than to the south. Comparatively few specimens were seen about Forrest City and Helena. The fruit appears to be relished much by children and

is quite nutritious, being likened by some to the banana, but we are not aware that it is used to any considerable extent by the residents. The valley of the White River is mentioned by Sargent as being one of the localities of its greatest development. It is not mentioned in our notes as having ever been seen on the ridge at any point.

THE LINDEN OR BASS WOOD.—(*Tilia americana*, Linnæus.)

The "bass wood" or "linn" has been observed but once on Crowley's Ridge and then some three miles south of Wittsburg. Possibly the trees seen were not indigenous. Inasmuch as it was not specially sought for many specimens may have been overlooked. It may be far less rare than our notes indicate.

WAIT-A-BIT, TEAR-BLANKET—(*Xanthoxylum clava-herculis*, Linnæus.)

The "wait-a-bit" or "prickly ash" occurs throughout the ridge and is especially abundant on the steep banks above Little Crow Creek. Its bark is an "active stimulant" and is a popular remedy for tooth-ache.

THE HOLLY—(*Ilex opaca*, Aiton.)

The holly occurs abundantly throughout the ridge, but the largest and finest trees were seen along Bolivar Creek, a few miles north of Harrisburg. The foliage is largely used in the north at Christmas time for purposes of decoration. The tree is an evergreen but is somewhat straggling in the arrangement of its branches and larger limbs, lacking symmetry. It occurs abundantly also near Jonesboro. The form appears to be confined to the region west of the ridge.

HOLLY—(**Ilex decidua*, Walter.)

This tree, also a holly, was not seen. It is listed on the authority of Sargent who reports it as occurring in southeastern Missouri, and as being especially abundant and large in southern Arkansas. It may therefore occur in our region or have been confounded with the preceding which is not unlikely.

WAHOO—(*Euonymus atropurpureus*, Jacquin.)

This is the "wahoo" and is common all through the northern half of the ridge in all lowlands along streams.

(**Rhamnus caroliniana*, Walter.)

This form was not seen. It has, however, been collected in Craighead county and doubtless occurs in various other localities.

BUCKEYE—(*Aesculus*, sp. indt.)

A species of buckeye is abundant near Crowley and near St. Francis. Neither flowers nor fruit were available and the species was not determined. It might have been *A. glabra*, which occurs abundantly in some parts of the state according to Harvey.

RED LEAVED MAPLE—(**Acer rubrum*, Linnæus.)

Said by Harvey to occur throughout the state. Only two maples, supposed to be this species, were seen south of Gainesville, near Paragould.

SUMACH—(*Rhus copallina*, Linnæus.)

This is the form which is so abundant on the margins of the prairies, engaged in the work of encroachment, and also is to be seen in quantity in many fields that have been long abandoned. In some sections of the United States, notably in Virginia, this tree affords, through its leaves and bark, a rich source of tannin and dye stuffs.

BLACK LOCUST—(*Robinia pseudacacia*, Linnæus.)

The black locust is one of the most common trees of the open glades throughout the ridge, on both sides. It is superior for use as fence posts, standing the action of moisture admirably.

COFFEE BEAN—(*Gymnocladus canadensis*, Lamarck.)

The coffee bean is of very common occurrence all along Crowley's Ridge, and on both sides of it. Near Wittsburg and Harrisburg, also near Boydsville, are many fine examples. Harvey says it is "common in the eastern portion of the state on the Quartenary," but it is by no means confined to soils that are of Pleistocene origin. Near Harrisburg the soils on which it occurs abundantly, about Spencer and Bolivar Creeks, are largely Tertiary. That is to say, they are sandy and clayey, and both are of Tertiary origin in this section. The seeds were formerly used "as a domestic substitute for coffee."

THE HONEY LOCUST —(*Gleditschia triacanthos*, Linnæus.)

On the roadway two miles south of Harrisburg, occurs a group of four of these trees, the only ones seen in the region. It is doubtless abundant.

WILD PLUM—(*Prunus americana*, Marshall.)

This species occurs in large patchy clumps along the L'Anguille and Cache Rivers. It was noticed in the upper portion of the valleys of Jack's Creek, near Paragould. A good sized grove exists near Goodwin, between that place and Palestine. It is, no doubt, of very common occurrence.

THE CRAB-APPLE—(*Pyrus coronaria*, Linnæus.)

This form is abundant around the prairies near Goodwin, and along the open lands to the west of Crowley's Ridge. I do not know whether it is used for purposes of food, though not entirely unsuited to such use. Fine examples also occur near Boydsville.

THE WITCH HAZEL—(*Hamamelis virginica*, Linnæus.)

The medicinal uses of this plant, which occurs throughout the hill country of eastern Arkansas, are well known. In some portions of Lee, St. Francis and Greene counties it was noted as constituting a considerable portion of the undergrowth in large areas.

SWEET GUM—(*Liquidambar styraciflua*, Linnæus.)

This is probably one of the most beautiful trees in the whole extent of forests. The sweet gum is abundant in all portions of the region on the slopes of the ridge and in the various river bottoms. Many very large specimens were noted in the lowlands west of Vanndale and Harrisburg. To the east of the ridge this species is an abundant form in all the open lands that are wet for the most of the year. It does not commonly extend far up on the hills, and no example of large trees are remembered as occurring near the top. The deep green foliage, the star shaped leaves, the graceful outlines, the great height, the trunk clear of limbs for many feet at times, all conspire to give this tree a degree of beauty that few forest trees possess. For cabinet work and interior finishing

the compact, close grained, heavy and hard wood seems to be especially well adapted. In the days before paraffine became the basis of most chewing gum the gum from this tree was largely employed for that purpose.

FLOWERING DOG-WOOD—(*Cornus florida*, Linnæus.)

This tree is common along all the small streams which flow from Crowley's Ridge, along their higher banks. A number of fine examples are to be seen near Brinkley, to the west, in the lower country. In Clay county many examples were seen along the hills facing the Cache.

BLACK GUM—(*Nyssa sylvatica*, Marshall.)

This is the "tupelo", "sour gum" or "black gum" and is an abundant tree in the swampy regions. It is easily distinguished from the following species which is more abundant still. It is found commonly in much dryer stations and is a taller tree, when at its maximum, than the following.

TUPELO GUM—(*Nyssa uniflora*, Wangenheim.)

Attention was directed to the large tupelo, as this species is called, at and near Paragould, in the basin of Eight Mile and Jack's Creeks. It thrives best in very wet situations. Sargent says "deep swamps and river bottoms subject to overflow, one of the largest and most common trees of the bottom lands of the lower Mississippi basin." The light wood of the roots is used as a substitute for cork in making floats for use with seines, nets and the like. It is also said to be extensively employed in turnery and for the manufacture of woodenware. The only articles which we have seen made from it are chopping bowls.

THE PERSIMMON—(*Diospyros virginiana*, Linnæus.)

The persimmon is of most abundant occurrence throughout the eastern portion of the state. It is found on nearly all soils but in greatest profusion and development in the bottom lands of the rivers and creeks. In nearly all fields that have been abandoned for purposes of agriculture the persimmon is now common. Its fruit is too well known to need description.

*THE BLUE ASH—(*Fraxinus quadrangulata*, Michaux.)

This species is reported by Mr. Letterman at DeVall's Bluff, and in northeastern Arkansas. The inner bark is used for making a blue dye on which character the common name of "blue ash" is based.

The ash trees of Arkansas will repay careful botanical investigation.

*THE WHITE ASH—(*Fraxinus americana*, Linnæus.)

I did not see this tree but Harvey says it "is common throughout the state." It is possible it was not recognized in distinction from the foregoing with which it is often confused by residents.

THE GREEN ASH—(*Fraxinus viridis*, Michaux.)

This is, properly, the green ash, but it is called in all this region by the name of blue ash. It is most abundant in the lowlands, especially so about Goodwin, on the margins of the prairie bordering Flat Creek, and all along the L'Anguille and Cache Rivers throughout their course. It does not ascend high up the hills as do some of the trees whose normal habitat is the lowland region. It is not used to any extent except for firewood.

CATALPA—(*Catalpa speciosa*, Warder.)

A number of specimens of catalpa grow in Forrest City, in Helena and at Wittsburg. Probably these were all introduced. Its chief use is for ornamental purposes. (See Plant List of the State, under Catalpa.)

SASSAFRAS—(*Sassafras officinale*, Nees.)

This species, the common sassafras, has been already mentioned in connection with its encroachments on the prairies. It is excessively abundant all over eastern Arkansas, north of the river of that name wherever our observations have extended. Along the base of Crowley's Ridge trees of this species two and a half feet in diameter are common. In all waste fields, on the margins of woodlands, in dry and sandy soils, even in wet or clayey soils, it is to be found. The bark is well known, since it enters largely into pro-

fessional medicine and in the more homely pharmacy of the housewife. The part used is chiefly the root and its bark. The decoction or infusion of sassafras has a pleasant and warm effect on the stomach. Though a useful plant, where excessively abundant, as it is in this region, it becomes a nuisance to agriculture.

WINGED ELM—(*Ulmus alata*, Michaux.)

This is the "winged elm" and is of very common occurrence all over our area. It was especially noticeable along the ridge, on both sides, though most of the ridge specimens were comparatively small. It is very easily detected among the elms by the winged character of the bark, which is corky and arranged in more or less flattened and roughened rows on each side of the smaller branches. In the St. Francis and White River bottoms, with their tributaries, it is very common and somewhat larger than on the ridge. It does not appear to be used for any economic purpose in this section, but in many other localities in the area of its distribution it is a valued source of material for wagon hubs.

THE WHITE ELM.—(*Ulmus americana*, Linnæus.)

The white or water elm is found throughout the valley of the White and St. Francis Rivers. Near Clarendon it occurs in considerable numbers; also west of Boydsville in the Cache valley.

(**Planera aquatica*, Gmelin.)

The "planer tree" is inserted on the authority of Sargent who says it is abundant throughout the state.

The red mulberry—(*Morus rubra*, Linnæus.)

The red mulberry is an abundant tree in the open glades and along the bottoms of nearly all streams which flow from the ridge. It is not a very pretty tree but may sometime prove to be of value in connection with the silk industry. South of Wittsburg there are great patches of this species.

THE SYCAMORE—(*Platanus occidentalis*, Linnæus.)

The sycamore is not common in the bottom lands west of Crowley's Ridge. In the lowland region east

of the ridge, along the St. Francis River, it is quite common and grows to an immense size. Several large specimens, growing near the mouth of Village Creek, southeast of Harrisburg, were measured and a circumference of twenty-nine feet found for the largest at five feet above the ground. This gives a diameter of over nine feet for this individual. The others were very large also and the whole constituted a most remarkable group of trees. The tree is easily recognized by the character of its bark and the peculiar twisting the trunk receives in the process of growing. Cross-sections of the body are used for butchers' blocks.

HICKORY—(*Hicoria aquatica*, (Michx. f.) Britt.)

This form is abundant all over the region in the lower lands and forms a considerable proportion of the mast on which the planter depends to fatten his stock. The fruit is bitter, resembles in color and shape the pecan, but it has no commercial value.

THE PECAN—(*Hicoria pecan*, (Marsh.) Britt.)

The pecan is very abundant in the St. Francis bottoms. There are some immense groves east of Wittsburg in the low and flat country, and they are reported as very common throughout the whole extent of the bottom lands of that stream. The great value of the fruit, which is much sought after all over the country, renders it a matter of great surprise that the immense crops are not annually gathered and marketed. The fruit commands a high price and is certainly very easily gathered. This tree forms a source of possible revenue that should not pass unnoticed.

A number of other hickories occur in this section of the state, but they were not studied carefully enough to warrant an attempt at specific determination. Little or no lumber appears to be marketed from this source though many of the trees are of very great size. The uses of the tough and hard, fine grained wood for axe helves, plow handles, carriages and a hundred similar objects are too well known to need mention. Among the hard woods of eastern Arkansas this

group of plants is a very conspicuous feature, one or another form occurring in almost every possible station and existing under the most diverse conditions.

BUTTERNUT OR WHITE WALNUT—(*Juglans cinerea*, Linnæus.)

The butternut occurs very often in various localties on the east side of the ridge. According to Harvey it is found nowhere else in the state except on the ridge. It is not sufficiently abundant to enter into the lumbering interests of the region though its value for interior finishings and for cabinet work is well known. It is yearly becoming more and more valuable for this purpose as the natural forests are being leveled by the injudicious lumberman—the man who dwells not on the possible needs of the future. It is quite likely that this form will eventually become of great economic value provided the existing specimens are carefully saved against the encroachments of the professional lumberer. Though of comparatively slow growth it will in the end repay protection.

THE BLACK WALNUT—(*Juglans nigra*, Linnæus.)

This tree has shared the fate of others mentioned to such extent that scarcely any are now to be found in the ridge country or near the railways. It has been sacrificed in a most remarkable manner all over the United States where it occurs and no single locality now offers much to the lumberer. It is a tree of comparatively rapid growth and may be cultivated in groves with great ease and become, in the end, a source of great revenue. There is, probably, no tree more sought after to-day than this species. The black walnut will soon be a thing of the past, so far as the natural forests are concerned. In our area it grows in the same situations as the other form last mentioned, but it is far more abundant. The best timber has long since, however, found its way to other markets.

THE BLACK BIRCH—(*Betula nigra*, Linnæus.)

A species of birch, called locally "black birch" is supposed to be this species. It is very common along the Cache

in Greene and Clay counties and along Jack's and Eight Mile Creeks, in the lowlands. No other birch was noticed.

WHITE OAK—(*Quercus alba*, Linn.)

The white oak is a beautiful tree and one which is most abundant all over eastern Arkansas, and on Crowley's Ridge where the underlying geologic formations are Pleistocene. It is very abundantly distributed along the slopes of the ridge even in those portions where the soils are too siliceous for its great development. Immense quantities of this grand tree have here been cut down and destroyed. In many places the forests have been thrice cut over and the better classes of timber are now all gone. There are yet, however, vast quantities of the largest and finest timber remote from the railways, and east of the southern half of the ridge. The use most common for this timber in this area is for the manufacture of barrel staves and heads, there being many mills along the foot of the ridge engaged in this industry. At some places, as at Poplar Bluff in Missouri, at Paragould, Harrisburg, and at numerous smaller places where there are mills the annual output is very great. Carload after carload of staves, in the rough or partially finished, or "knocked down" after fitting, are to be seen in transit daily in all parts of the region. There is a most wanton destruction of valuable timber in this industry, which does not use all the tree, only a small portion of it being available. The remainder is left to rot, or is made into great piles and burned. No use is made of the ashes, which might be gathered and leached with profit. The bark, too, is a complete loss notwithstanding that it is rich in tannin and might be utilized in the manufacture of leather, after having first been treated on the ground to extract this valuable product. Not only does the cupidity of men incite them to the felling of the largest and most perfect trees but, in common with all suitable oaks of other species, many hundreds of thousands are annually cut into railway ties and shipped out of the state to regions less favored. The numbers of ties made and sold in Arkansas would seem incredible to one not familiar with the

actual state of the industry. The product goes far to the west to the states with treeless plains, as Nebraska, Kansas, Colorado, to say nothing of the thousands utilized nearer home and at home in railway construction. The prices received by no means represent the actual value of this tree which is rapidly becoming a matter of history in this part of the state.

The barrel timber is used largely for wine and whisky casks, these liquids requiring a fine and closed grained wood to retain the product. Many thousands of these barrels, in unfinished condition, or rather in "knock down" condition are sent to Europe where they are used for similar purposes. Petroleum, which likewise requires barrels of fine texture, is also shipped largely in casks made from this wood. Perhaps it is safe to say that the wood of the white oak is put to more common uses than that of any other forest tree in the United States. There is scarcely a branch of wood-working industry which does not use it in one way or another.

THE WATER OAK—(*Quercus aquatica*, Walter.)

The water oak is found associated with the willow oak (*Quercus phellos*) in considerable numbers in all eastern Arkansas. It is very common in the slash regions of the Cache and L'Anguille, and does best on poor and wet soils. It does not attain a very great size, at least it did not seem to us to ever grow very large. It is used for posts and seems to be to be well adapted to that purpose.

THE OVERCUP OAK—(*Quercus lyrata*, Walter.)

This is one of the most abundant and largest oaks of the St. Francis bottoms, and is likewise one of the white oaks. It is commonly called the overcup oak, from the peculiar characters of the cupules which hold the fruit. The acorn is nearly entirely covered. The wood is cut and marketed with the white oak and is not often discriminated from it. Like the white oak it is largely employed in the manufacture of such barrels as need to be made from a close textured wood.

THE MOSSY-CUP OAK—(*Quercus macrocarpa*, Michaux.)

As implied in the name the acorns of this tree are very large and are further distinguished by a heavy and long fringe. To this tree therefore the common name of mossy-cup oak has been popularly applied. It is very abundant and is of especial value for fencing purposes in this portion of Arkansas. This species resists the action of wet soils, or of water in soils, better than any other American oak. It is therefore correspondingly valuable. It is very common and grows very large.

THE COW OAK—(*Quercus michauxii*,Nuttall.)

This species, called "cow oak" by the people, is a common form, growing to be a rival of the white oak in the bottoms of the St. Francis, where it attains its best development. It is a source of abundant mast for stock and is much sought by it. The acorns are large and sweet. While a close grained wood and largely used in barrel manufacture it does not hold liquors as well as either the white oak or the overcup oak, at least such is its reputation about the mills. Many, perhaps most of the barrels used for pork packing are made from the wood of the cow oak, a purpose for which it is admirably adapted.

THE PIN OAK—(*Quercus palustris*, Du Roi.)

Possibly the pin oak is the most abundant oak of the slash country. From Wynne north along the base of Crowley's Ridge one is never out of its range. It is used chiefly for firewood and for railway ties, thousands of the middle sized trees being exported in the latter form.

Of other oaks not less than six or eight additional species might be distinguished. To the professional botanist, interested in questions of geographic distribution, abundance, crosses, variations, species, influence of habitat, and similar matters, this region offers a most inviting field. The prevailing features of the forests are contributed by the oaks and one is never, except in the heart of a cypress swamp, out of sight of a half dozen forms at one time.

THE WILLOW OAK—(*Quercus phellos*, Linn.)

The willow oak is readily distinguished by the character of the foliage, the leaves closely resembling those of the willow. It is a very abundant tree in Arkansas, attaining its greatest development in the low and wet lands west of Crowley's Ridge. It is usually regarded as indicative of poor land.

THE BEECH.—(*Fagus ferruginea*, Aiton.)

The beech is of erratic distribution along Crowley's Ridge, but does not appear to occur in any quantity in the lowlands to the west. It occurs abundantly from Helena to the Missouri line on both sides of the ridge, but most commonly along the slopes of its west face. On the top of the ridge none was noticed north of Jonesboro, though it is quite common south on the highest ridges. Scattering trees occur for the most part in and south of St. Francis county, while west and north of Gainesville and Jonesboro, in the Cache second bottoms, the species is most abundant and large. Many of the largest examples noted in the south of the ridge were either hollow or dry at the heart, which fact gives the tree certain peculiar features. It does not seem to be as common in the St. Francis bottoms or along the east side of the ridge as on the west, but no comparative notes were made on this subject. Except for firewood the tree appears to have no use in this part of the country.

THE PINES.

There remain but two trees especially worthy of mention among the timber resources of this area and they are both members of the great family Coniferæ, or cone-bearing trees. The physical conditions under which each thrives are of the most diverse kind.

THE CYPRESS—(*Taxodium distichum*, Richard.)

The cypress is familiar to all who dwell in the eastern or southern portions of Arkansas. As is so well known the tree thrives in swamps and other wet and low lands; it often, as in the valley of the L'Anguille, stands in the very middle of the sluggish streams.

From its great utility the cypress is much sought after by

the lumbermen. Its uses are very diverse, but it is especially adapted to the manufacture of shingles, into which article of commerce many thousands of feet are annually converted. There are several mills along Crowley's Ridge at Madison, Paragould and St. Francis where shingles are made in great quantity. The powers of resistance which this wood offers to the action of wet and damp stations, as in fence building, telegraph poles, electric light poles and similar uses has caused it to be in great demand. Many hundreds of the smaller sized trees are employed for poles.

The best trees that are accessible are now somewhat within the borders of the cypress swamps, the more easily reached having, as a rule, already been marketed. The nature of the places best suited to the growth of the cypress renders difficult its cutting so that its price is slowly but steadily advancing. "The most valuable timber has now, however, disappeared from the immediate neighborhood of the low river banks easily accessible at seasons of high water during every winter and spring. Only groves standing remote from the banks of the water courses, and which are only accessible to the raftsman during exceptionally high stages of water, now supply this lumber. * * * The shallow lagoons, covered with water except during seasons of prolonged drought, and called cypress creeks, present in the spring of the year a strange sight. No object meets the eye between the immense trunks of the mighty trees, as in these cypress groves no other tree nor shrub can live in the dark shaded, water covered soil. These reservoirs of drainage, generally without an outlet, are called cypress lakes if the water in any part of them, too deep to allow the growth of trees, confines the cypress to their more shallow borders. Here the cypress arrives at its greatest dimensions and produces timber of the finest quality." This statement, originally applied to the cypress swamps of the Yazoo region in Mississippi, is true to a very great extent of the cypress regions of the St. Francis and White Rivers. Perhaps the great body of cypress in northeastern Arkansas is still standing in the valley of the White River, but even here the most easily accessible has been removed. From the top of Crowley's Ridge, looking either to the east or the west, at those points which com-

mand the valleys of the St. Francis and the Cache, the cypress areas can be readily made out by the observer. The tops of the giant trees tower far above the heads of the intervening forests and give one the location of the swamps for hundreds of square miles. It is evident to a person thus situated that immense quantities of this tree still exist in Arkansas and that this region will yet supply vast quantities of valuable cypress timber. Into the depths of the greater swamps the lumberman has not yet penetrated.

THE SHORT LEAVED PINE—(*Pinus mitis*, Michaux.)

This is the short leaved pine of authors and is practically the only species growing within the state north of the Arkansas River. Its distribution has not been carefully studied in the areas outside of Crowley's Ridge on which its occurrence was carefully noted. Its distribution is somewhat erratic but, after all, is readily seen to conform to certain physical conditions imposed by the character of the soils.. It rarely descends to the base of the ridge and only then in straggling representatives. The lowest trees noticed, small ones at that, were about two miles north of Wittsburg in Cross county, where a few saplings were found near the road not far from Copperas Creek. The highest points in the ridge in Cross county where the soil is siliceous or sandy have a growth of pine, none of which is very lrage. The presence of numerous large pine stumps, however, tells the story of this tree in language that cannot be misunderstood. Near Harrisburg, Vanndale, and Jonesboro are to be found, on the tops of the highest hills, stretching away in long straggling lines, what now remains of the pine forests of this portion of the ridge. But in Greene and Clay counties, and on some of the more elevated hills of Craighead county, there is still standing many fair sized pine trees. The largest and best have, however, been cut off, the region having been twice cut over. Farther from the railways there is still considerable pine standing, much of it large and fine. A typical locality is about Hardy's mill not far from Gainesville. Here, on the high hills that are composed of the Tertiary sands and gravels, there are still many large pines. But their entire removal is the question only of a short time.

As in the case of the white oak, so here there is wanton destruction of enormous quantities of timber, little of which has any value for the lumberman. In many cases a single cut is taken and the balance left to decay or to be burned in the too frequent forest fires. Nothing is done with the refuse pine. Great quantities of slabs and sawdust are made in sawing the lumber, and these are all suffered to rot or are burned when the latter plan is easier than the removal of the entire plant. There have been devised numerous cheap processes for the distillation of turpentine and other products from the pine which, it would seem, could be practiced here with profit to the producer and with much less waste.

The pine bearing hills are readily distinguished from long distances by the color of the foliage. Here and there may be seen a dark head of forest towering far above the masses of lighter green which characterize the deciduous forest. These darker masses invariably mark the areas of pine. That they are the highest and the least suited to agricultural purposes has already been noted in this report. It may now only be repeated that the pines are found along Crowley's Ridge on lands of but little use for agricultural purposes after the timber has been removed.

Of the pine reported for the Crowley's Ridge region by the the agents of the tenth census, which estimate was made for 1880, comparatively little now remains. That census gave the following figures, which may not be wholly devoid of interest in this connection:

Phillips county....	21,000,000	feet	board	measure.
Lee county.........	14,000,000	"	"	"
St. Francis county.	7,000,000	"	"	"
Cross county........	54,000,000	"	"	"
Poinsett county....	45,000,000	"	"	"
Craighead county..	18,000,000	"	"	"
Greene county......	38,000,000	"	"	"
Clay county.........	3,000,000	"	"	"

It is safe to say that not one tenth of this timber is standing at the present time. The great pine producing areas south of

the Arkansas River form, at the present time, the object of attention from the lumber manufacturer, so that it is possible that the pine producing areas in our section may have time for recuperation, since pine replaces pine in this region.

CHAPTER XXIV.

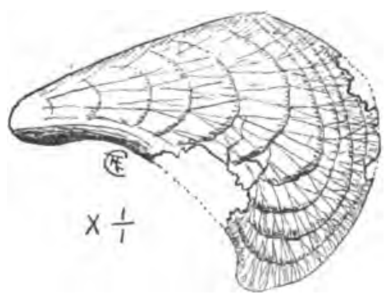
Description of a New Pelecypod Mollusk of the Genus Mytilus, from the Tertiary of Eastern Arkansas.

By R. Ellsworth Call.

Family MYTILIDÆ.

Genus *Mytilus*, Linnæus.

Mytilus hamatoides,* sp. nov.



Shell moderate in size, thin, equivalve, somewhat convex; lines of growth well marked and numerous, becoming crowded near the posterior margin; impressed lines departing from the umbones and bifurcating at each growth line, the crenulations thus caused furnishing a characteristic sclupturing; hinge margin nearly straight or but slightly curved, little more than one half the total length of the shell; ventral border flattened and sulcate, indicating byssiform attachment in life; posterior margin much curved, resembling closely its modern congener.

Position and locality:—Claiborne beds, Eocene Tertiary; Little Crow Creek, St. Francis county, Arkansas.

Remarks.—This form is represented by six specimens, most of which are broken badly by the vicissitudes of transportation, the largest and best preserved of which is made the type. It

* Etymology: Latin hamus, a hook.

occurs attached to the valves of *Ostrea sellæformis* in the *Ostrea* beds described elsewhere in this report. The best examples were procured by breaking the larger masses of shell marl found near the middle of the lower bed. Seen from above and near the upper margin the sculpturing closely resembles that of the common *Modiola plicatula*, Lamarck, of the Atlantic coast. The entire aspect is that of *Mytilus hamatus*, also recent and abundant from Long Island Sound to Florida, and from the Gulf of Mexico to Vera Cruz.

DESCRIPTION OF THE PLATES.

Plate I., Figure 1.

(For description see p. 150.)

Section on Dry Run, one mile east of Forrest City, 5 N., 3 E., section 35, southeast quarter of the southeast quarter.

No.	Ft.		Total.
1.	2.	Light colored, thin siliceous humus	2
2.	15.	Compact, fissured loess	17
3.	3.	Loess-like, reddish and somewhat sandy clay	20
4.	10.	Loess-like, light colored clays	30
5.	8.	An irregularly disposed, indurated, reddish clay	38
6.	7.	Party-colored clays and sands, with limonite	45
7.	5.	Irregularly stratified gravels	50
8.	3.	Blue-black clays, with thin sand partings	53
9.	10.	Regularly stratified blue clays	63
10.	2.	Cross-bedded, indurated sands, coarser below	65
11.	1.	Cross-bedded, party-colored sands	66
12.	5.	Dark blue stratified clays	71
13.	5.	Shell-marl	76
14.	1.	Dark blue clay	77
15.	5.	Clay with green sand and abundant fossils	82

Plate I., Figure 2.

(For detailed description see p. 159.)

Section in the Memphis and Little Rock Railway cut at Forrest City, St. Francis county.

No.	Ft.		Total.
1.	4.	Light colored, siliceous humus	4

2.	30.	Loess, weathering into vertical cliffs..................	34
3.	1.	Fine bleached gravels....................................	35
4.	6.	Bluish clay, with limonitic nodules near the base..	41
5.	2.	Limonitic clay..	48
6.	6.	Yellowish clay, with nodules of limonite............	49
7.	8.	Party-colored sands with some gravel...............	57
8.	10.	Fine, hard, compact, blue stratified clay............	67

Plate I, Figure 3.

(For detailed description see p. 11.)

Section on the Arkansas River, at Red Bluff.

No.	Ft.		Total.
1.	½.	Light colored, thin, sandy humus.....................	½
2.	2½.	Clayey sand, with limonitic nodules..................	3
3.	½.	Dark, earthy clay..	3½
4.	4.	Mottled sands and clays..................................	7½
5.	10½.	Indurated irregularly stratified, red sandstones.....	18
6.	8.	Soft yellow, to red sands................................	26
7.	20.	Dark blue, regularly stratified clay..................	46
8.	½.	Dark brown, indurated sandstone......................	46½
9.	23.	Light blue clay...	69½

PLATE I.

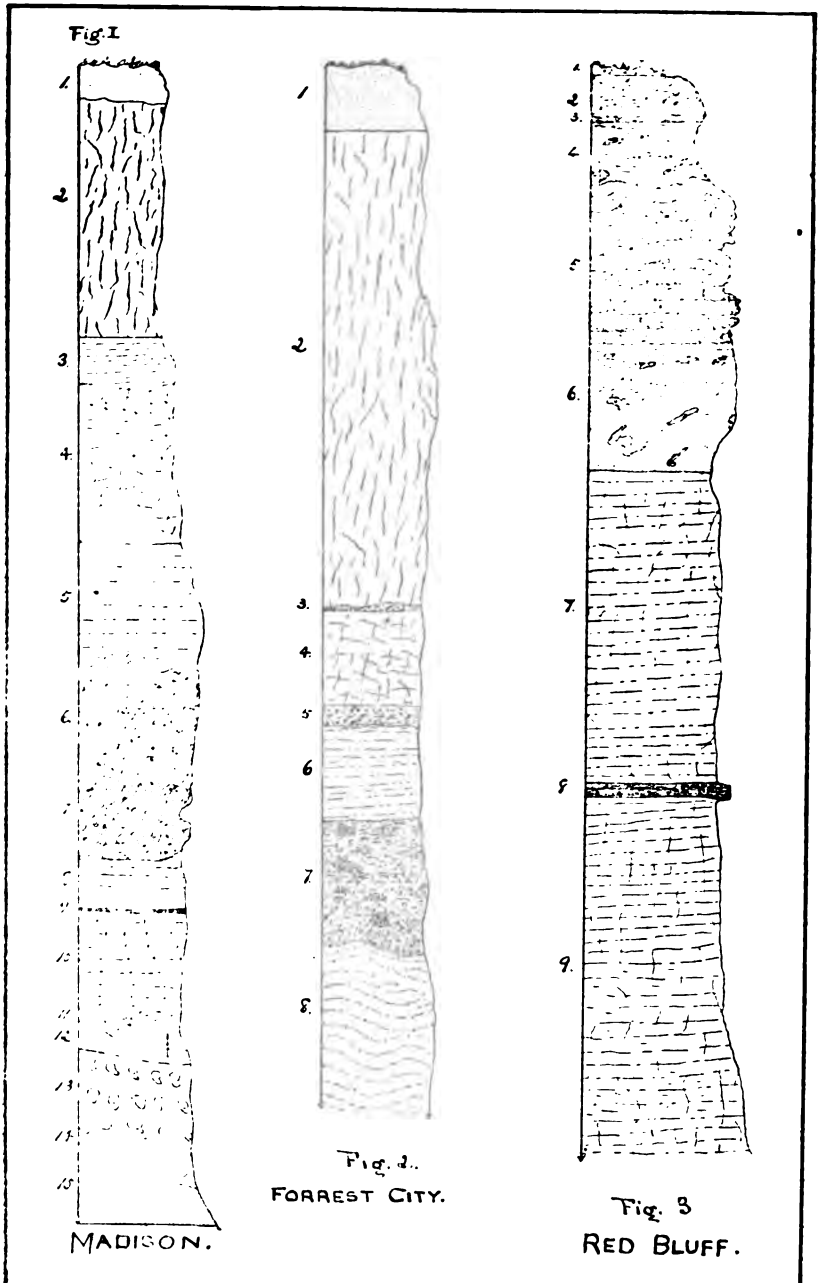


Fig. I
1
2
3
4
5
6
13
14
15
MADISON.
1
2
3.
4
5
6
7
8
Fig. 2.
FORREST CITY.
2
6.
7.
9.
Fig. 3
RED BLUFF.

Plate II., Figure 1.

(For details see p. 22.)

Section at Augusta, on White River, Woodruff county.

No.	Ft.		Total.
1.	2.	Humus	2
2	½-1.	Brown, clayey sand	3
3.	8.	Stratified, sandy clay	11
4.	10.	White sands	21
5.	2.	Indurated, reddish sand	23
6.	4.	Sands with occasional pebbles of chert	27
7.	1.	Indurated reddish sands	28
8.	2.	Clayey white sand	30

Plate II., Figure 2.

(For details see p. 15.)

Section of a well in the town of Beebe, made from a shaft sunk to obtain an Eocene marl.

No.	Ft.		Total.
1.	1.	Humus	1
2.	10.	Whitish sandy clay	11
3.	4.	Hard, reddish clay, with little sand	15
4.	13.	Light gray, stratified, clayey sand	28
5.	1.	Marl with abundant fossils	29
6.	35.	Blue, clayey marl, with numerous fossils	64
7.	47.	Soft, blue paleozoic slate	111
8.	?	Sandstone	—

Plate II., Figure 3.

(See page 36.)

Section in east side of Crowley's Ridge, at Big Spring, two and a half miles north of Helena.*

* Owing to the scale adopted, the size of the plates in this volume is inadequate to represent the entire thickness of each member of the series in this section. In the second member, therefore, the blank portion will represent an omission of sixty-five feet, while the similarly distinguished portion of the third member represents seventy-five feet.

No.	Ft.		Total.
1.	3.	Humus	3
2.	80.	Fossiliferous loess	83
3.	90.	Stratified Orange Sand	173
4.	2.	Yellowish, sandy clays, with occasional pebbles	175
5.	20.	Homogeneous, light colored, fine, stratified clays	195
6.	5.	Gravels and sands	200
7.	10.	Sandy clays	210

The bottom of this section is from two to five feet above high water level of the Mississippi River.

Plate II., Figure 4.

(For detailed description see pp. 4–5.)

Section at foot of North Beech Street, Pine Bluff, in bank of the Arkansas River.

No.	Ft.		Total.
1.	1.	Humus, with occasional pebbles	1
2.	5.	Light colored yellowish clay	6
3.	1½.	Blue carbonaceous clay	7½
4.	8.	Arenaceous clays, light yellowish in color	15
5.	1.	Sand, usually pure white	16
6.	2.	Soft, white sand with occasional pebbles	18
7.	12.	Fine, light gray clay or slate	30

Plate II., Figure 5.

(For details see p. 60.)

Illustrating the upper members of the Crowley's Ridge strata. The locality is two miles east of Wynne, at the highest point in the cut of the Bald Knob and Memphis branch of the Iron Mountain, St. Louis and Southern Railway.

No.	Ft.		Total.
1.	2.	Sandy, light colored humus	2
2.	20.	Loess, tough, with concretions, nonfossiliferous	22
3.	12.	Irregular layer of brick red clay, loess-like, hard, fine, lighter colored below	34
4.	12.	Light colored, very fine, loess clay, becoming	

somewhat indurated under atmospheric influences, weathering into vertical cliffs................ 46

There can be little doubt that the last three members are different phases of the same thing. This would give the loess a thickness of some forty-four feet in this section.

Plate II., Figure 6.

(For details see p. 57.)

Section in the beginning of the great Wynne cut through Crowley's Ridge.

No.	Ft.		Total.
1.	2.	Humus	2
2.	20.	Loess-like clay	22
3.	2.	Gravel bed, with sand pockets	24
4.	6.	Variegated, sandy clays	30

PLATE II.

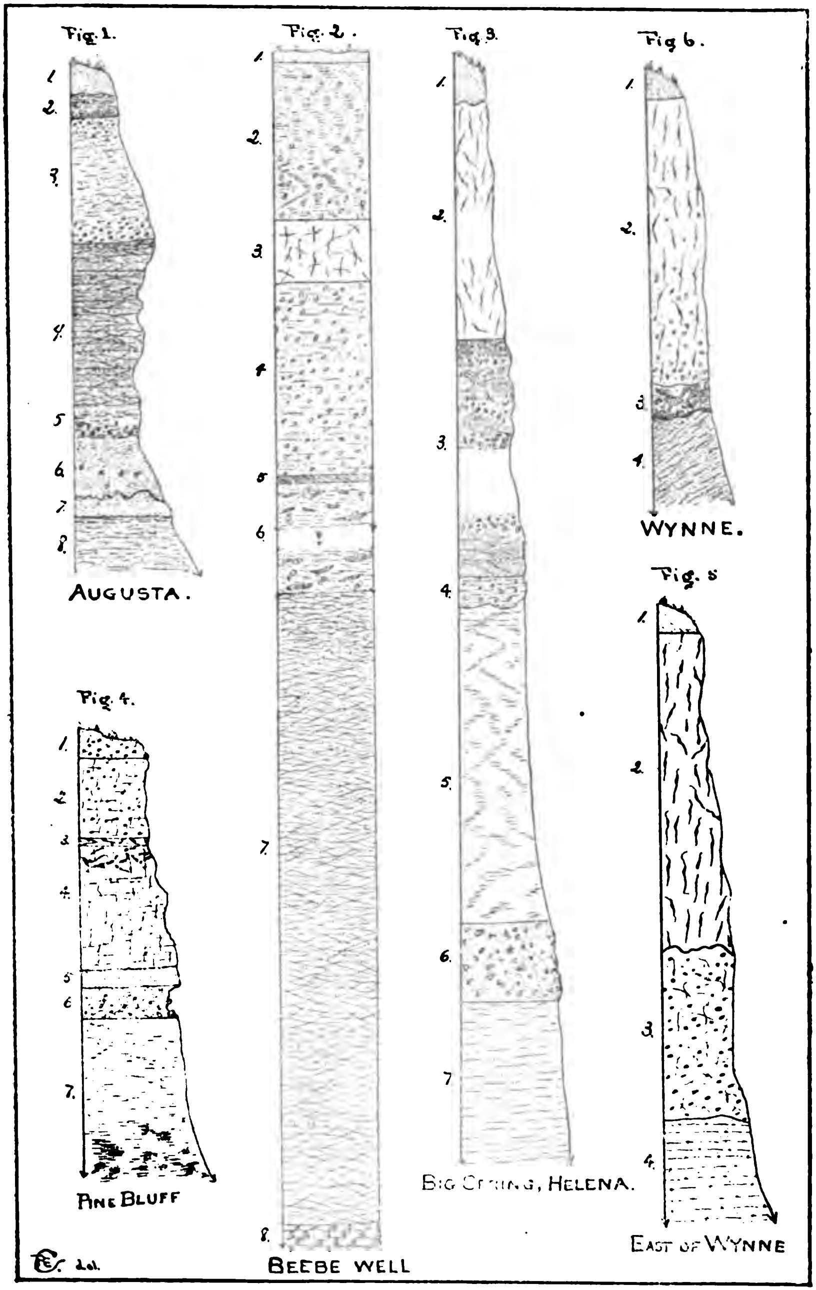


Fig. 1.
AUGUSTA.
Fig. 2.
BEEBE WELL
Fig. 3.
BIG SPRING, HELENA.
Fig. 4.
PINE BLUFF
Fig. 5
EAST OF WYNNE
Fig. 6.
WYNNE.

Plate III., Figure 1.

(For details see p. 166.)

Illustrating the relation of Pleistocene and Tertiary strata on Spring Creek, in the heart of Crowley's Ridge.

1. Humus.
2. Modified, fossiliferous loess, separated from older loess by an old surface of erosion.
3. Typical loess.
4. Reddish clays, representing the first stages of loess deposition; occasional chert pebbles in the bottom.
5. Party-colored, cross-bedded sands.
6. Pebble bed.
7. Blue clays.

Plate III., Figure 2.

(For details, see p. 20.)

Sketch map of region at Bald Knob, on the west margin of the Tertiary.

a. Carboniferous sandstones.
b. Scarp making west limit of observed Tertiary deposits.
A–B. Quarry in Carboniferous sandstone.
W. Wells from which the sequence of the Tertiary strata was obtained.

Plate III., Figure 3.

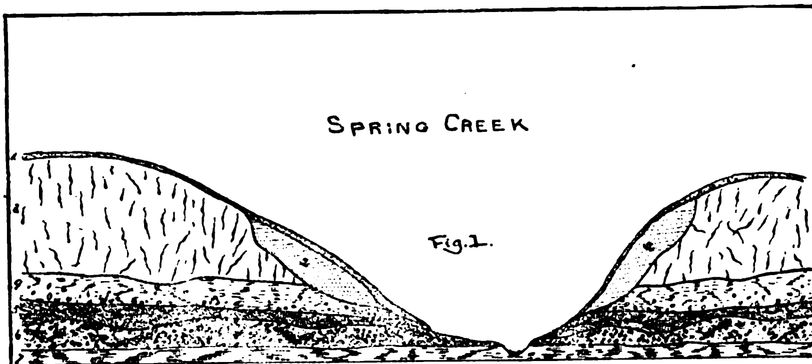
(See p. 19.)

Cross section showing the relation of Carboniferous and Tertiary strata at Bald Knob quarry. This section is based on data obtained at A. and d. of figure two, above.

Plate III., Figure 4.

Outline cross section of Crowley's Ridge, showing the vertical distribution of the modified loess on the east and west sides and on Crow Creek. The altitudes are those above sea level, the datum line being the profile of the Memphis and Little Rock railway, reduced from Mississippi high water level at Memphis. The heavy lines represent this modified loess.

PLATE III.


SPRING CREEK
Fig. 1.

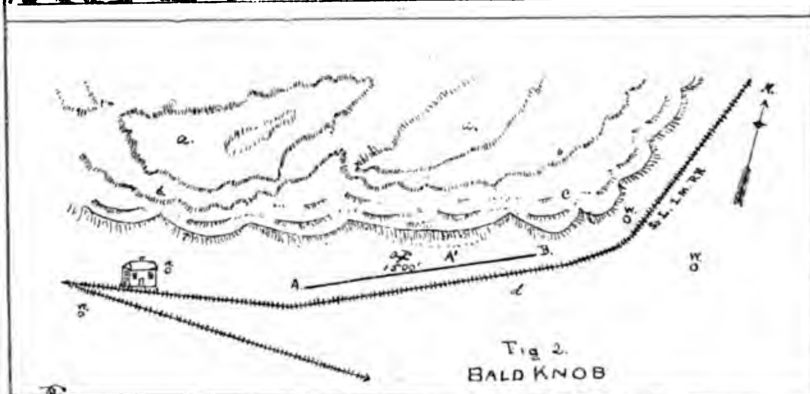


Fig. 2.
BALD KNOB

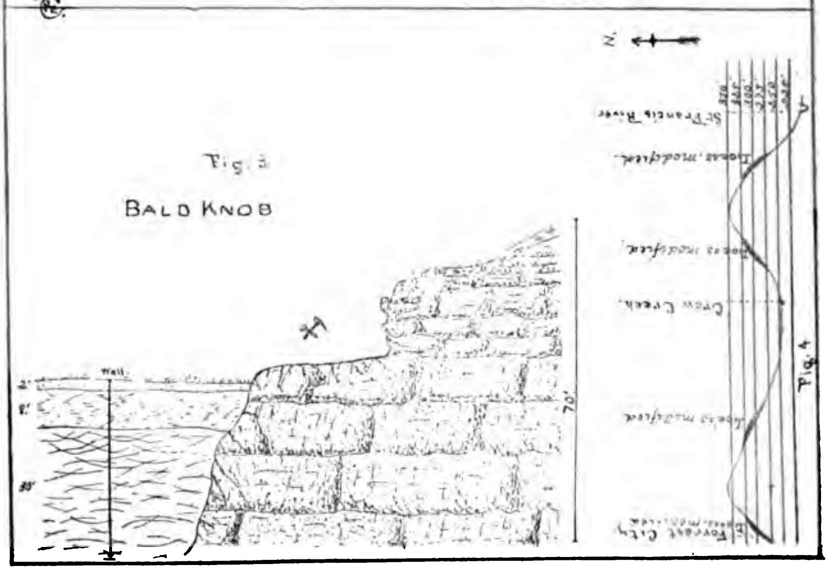


Fig. 3.
BALD KNOB
Wall
70'
Fig. 4
St Francis River
Crow Creek
Forrest City

Plate IV., Figure 1.

(For details see p. 24.)

Section at Augusta, on the White River.

No.	Ft.		Total.
1.	2.	Sandy, light colored humus..............................	2
2.	2.	Clayey sand, brownish in color, somewhat indurated near the top, but becomes softer and more sandy below..	4
3.	8.	Reddish sand, clayey, distinctly stratified. Contains small scattered limonite nodules near the top, and abundant large, soft, limonitic nodules near the bottom..	12
4.	10.	White, stratified, cross-bedded sands..................	22
5.	2.	Indurated somewhat reddish, vitreous, fine sand, with some clay and much limonite in sandy nodules..	24
6.	4.	Bluish white, irregularly stratified coarse sand, with considerable clay. This member contains, also, an occasional chert pebble; down the stream a short distance it thickens to five feet............	28
7.	1.	Reddish, indurated, almost pure sand, brown below, regularly stratified and generally mottled.........	29
8.	2.	Clayey, white stratified sand of which only one and a half feet was above water.....................	31

Plate IV., Figure 2.

(See p. 24.)

Sketch map of the region immediately adjoining Augusta. The cemetery crowns a ridge which is, like Crowley's Ridge, a product of erosion. The ancient and the present channels of the White River are indicated. The section in figure I. is built up from sections taken at A, B and C.

Plate IV., Figure 3.

(For details see p. 40.)

Section on Porter Street, in the city of Helena.

1. Humus.
2. Modified loess, abutting against 3, containing chert below.
3. Sandy loess, formed from the adjacent strata.
4. Typical loess, with abundant concretions.
5. Orange Sand.
6. Party-colored sands with pebbles of chert.

The section represents the face of a cliff which has been subject to erosion, the member 8 being made up of 1, 4 and 5, while 6 enters largely into its composition below. Modified loess, 2, lies against the rearranged material.

Plate IV., Figure 4.

(See p. 41.)

Section in a fresh cutting on the Jewish Prussian cemetery, north of the city of Helena. The lines X–X and Z–Z, indicate two widely separated periods of erosion, forming troughs, which are filled respectively with typical loess, A, A, and with modified loess, L. A fills a trough or channel eroded in early Pleistocene Orange Sands. The modified loess fills a newer channel begun in its older congener.

PLATE IV.

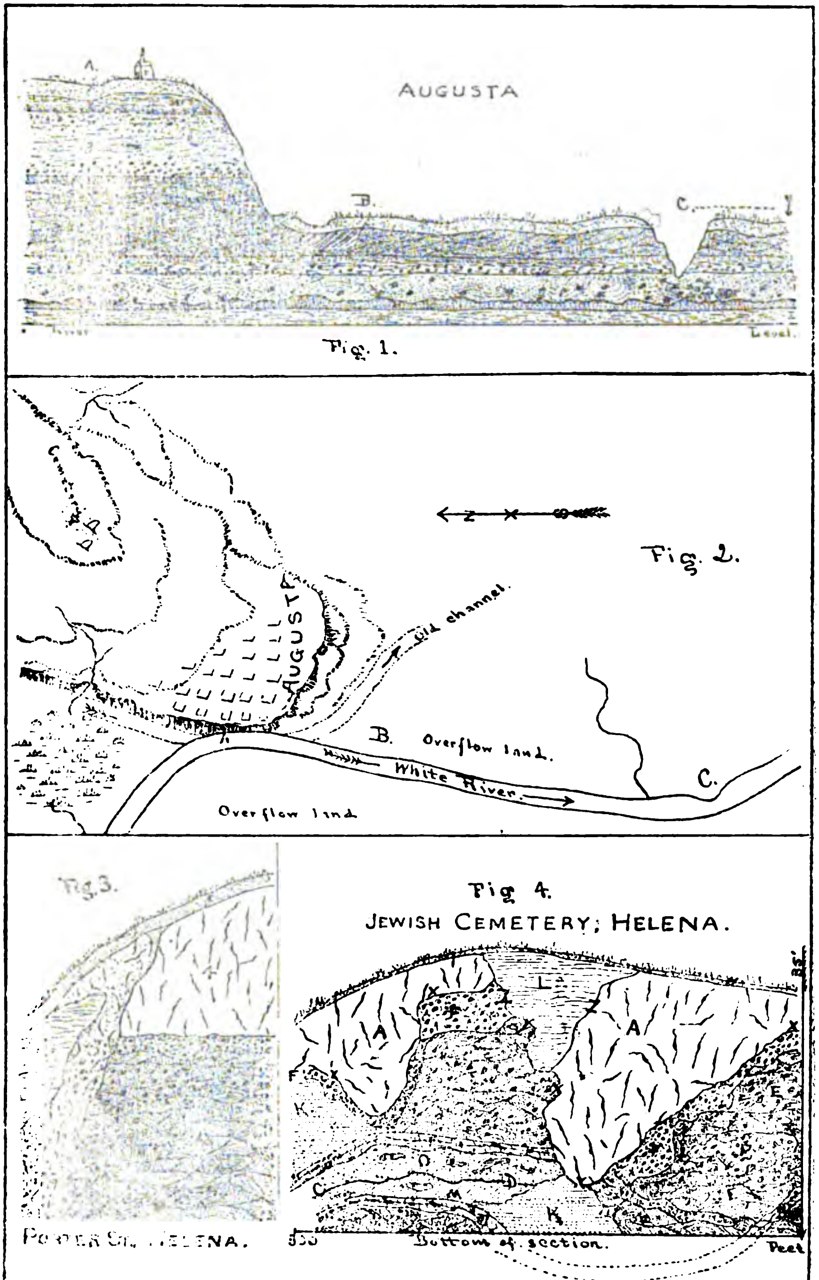

AUGUSTA
A.
B.
C.
Fig. 1.
Fig. 2.
AUGUSTA
Old channel
B.
Overflow land.
White River
C.
Overflow land.
Fig. 3.
Fig 4.
JEWISH CEMETERY; HELENA.
A
L
A
F
K
E
C
M
K
Bottom of section.
Feet

Plate V.

East to west and north to south profiles across St. Francis county. The former is the profile of the Memphis and Little Rock railway. The dotted line through Crowley's Ridge represents the railway profile and indicates the depth of the cutting.

The second profile is that of the Helena branch of the St. Louis, Iron Mountain and Southern railway.

PLATE V.

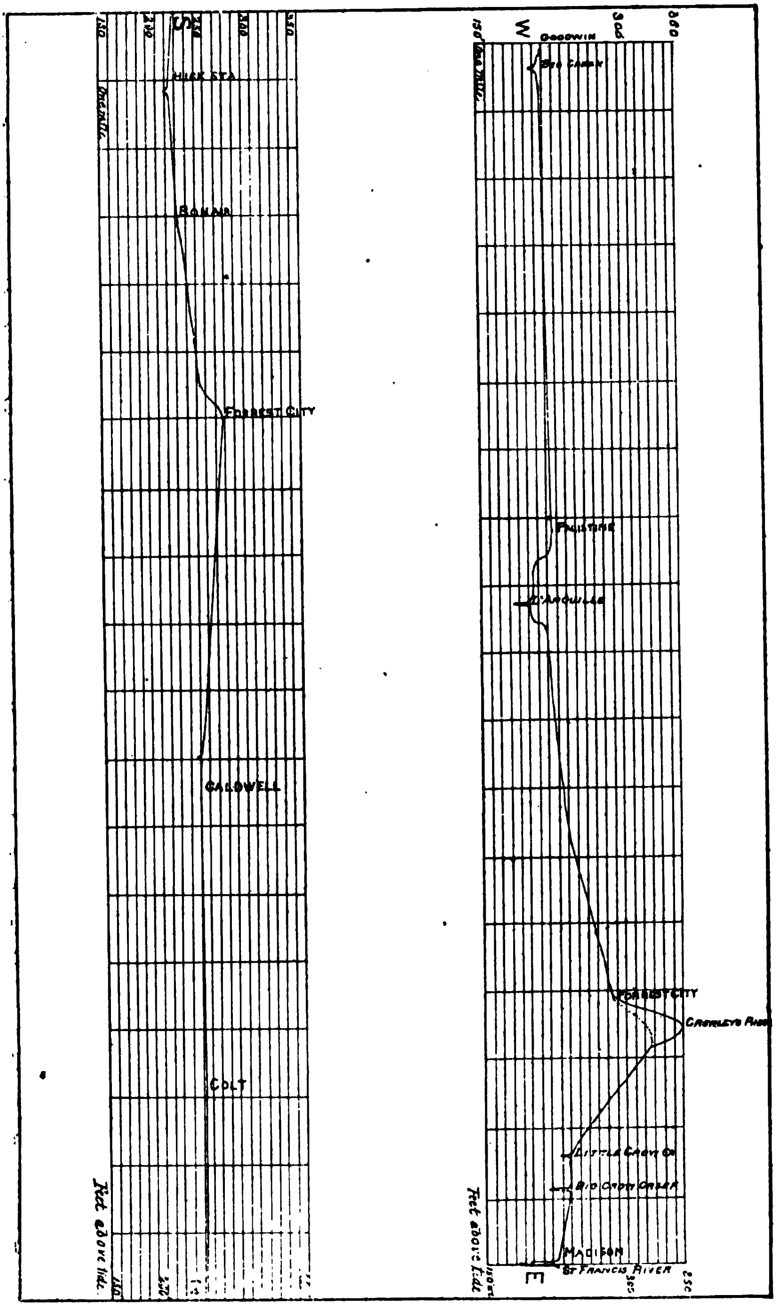

S
HICK STA
BONAIR
FORREST CITY
CALDWELL
COLT
Feet above tide.
W
GOODWIN
BIG CANEY
PALESTINE
CARONVILLE
FORREST CITY
CROWLEYS RIDGE
LITTLE CROW CR
BIG CROW CREEK
MADISON
ST FRANCIS RIVER
E
Feet above tide.

Plate VI., Figure 1.

(For details see p. 169.)

Section on the east side of Crowley's Ridge, in St. Francis county near its southern limit, in 4 N., 4 E., section 26.

No.	Ft.		Total.
1.	2.	Siliceous, light colored humus	2
2.	25.	Loess	27
		At A the modified loess is fossiliferous and abuts against 2.	
3.	8.	Reddish, sandy clay	35
4.	25.	Bluish clay	60
5.	2.	Brown lignite	62
6.	3.	Fire-clay	65
7.	30.	Stratified bluish and black clays	95

This section shows no Orange Sand though the bed of the run near by contained innumerable characteristic chert pebbles, indicating its near proximity. No exposure could be found, however, perhaps owing to the very heavy talus of the locality.

Plate VI., Figure 2.

(See detailed description on p. 157.)

Sections of the pit at the south end of Crowley's Ridge, near Madison, and in a portion separated from the main ridge by Big Crow Creek.

No. 6 is a compact, jointed blue clay, filling a considerable depression in the sands of no. 7. These latter are the usual cross-bedded, party-colored sands of the upper part of the Tertiary of the region. The west extremity of no. 6, in that portion of the pit which is shown on the left of the figure, is tripartite. The pebble bed of the Orange Sand overlies the whole.

The section at the extreme left represents the sequence for sixty-five feet at the center of the pit, along the line A–B. It is introduced as showing how, in a well section, similar and equivalent strata may be repeated and listed as separate members. The section shows three hundred feet of the horizontal projection.

The remaining members of this section are, as in the Little Crow Creek section, the same as those in figure I., plate I.

PLATE VI.

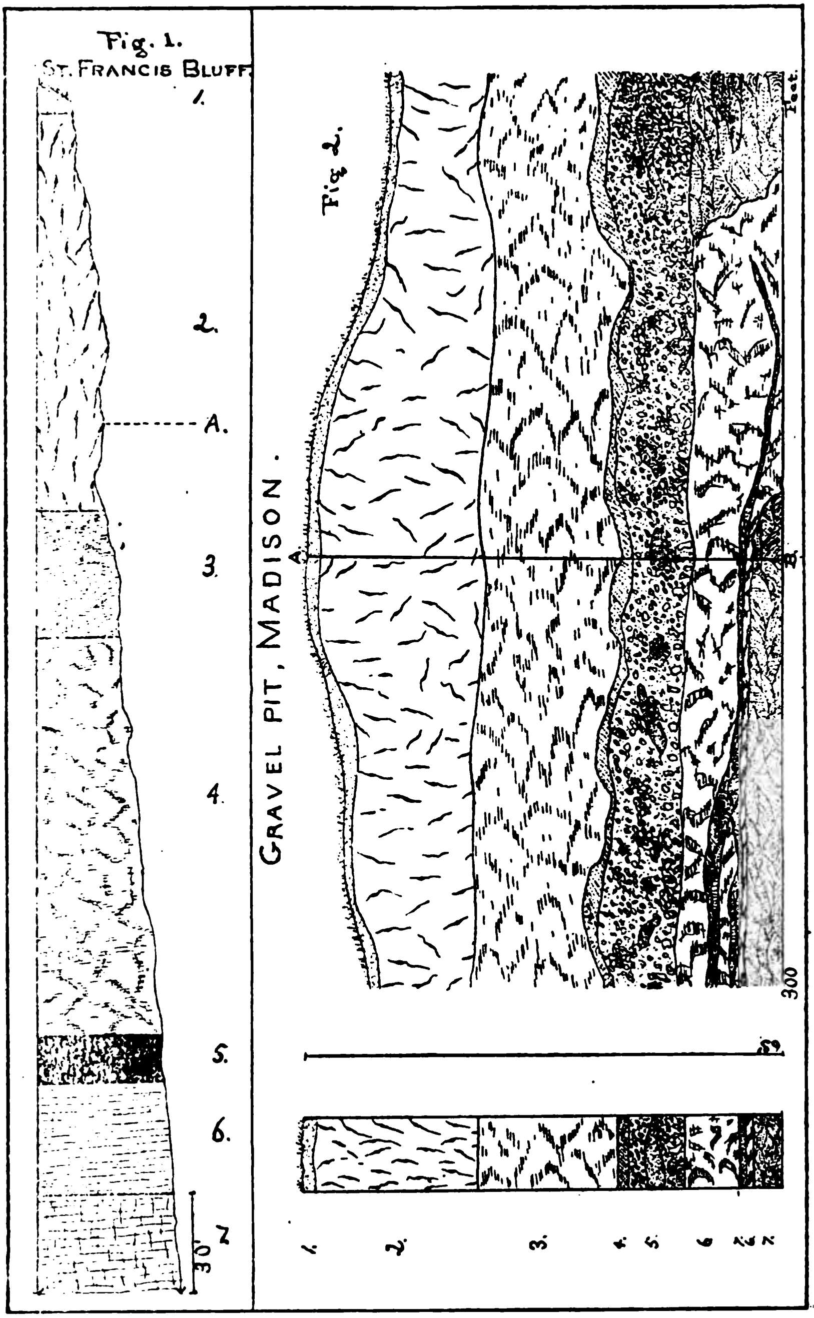


Fig. 1.
St. Francis Bluff
1.
2.
A.
3.
4.
5.
6.
7
30'
Fig. 2.
Gravel Pit, Madison.
A
Feet
300
1.
2.
3.
4.
5.
6

Plate VII., Figure 1.

(For details see p. 169.)

Illustrating a section in the west margin of the village of Wittsburg.

Plate VII., Figure 2.

(For details see p. 70.)

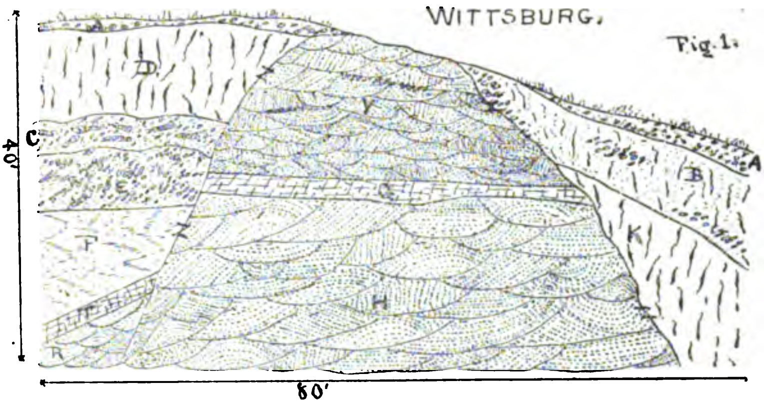
Cross-section of Copperas Creek bluff.

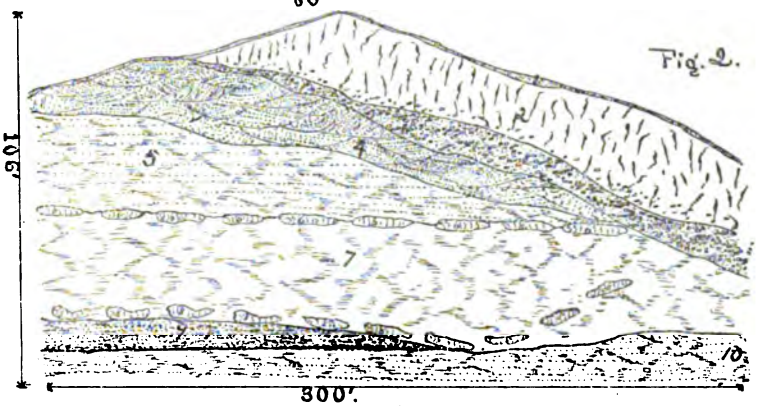
Plate VII., Figure 3.

(For details see p. 74.)

Section in the creek near Cherry Valley, showing the relations of the Pleistocene and Tertiary. The latter is supposed to begin with number three of the section.

PLATE VII.





COPPERAS BLUFF.

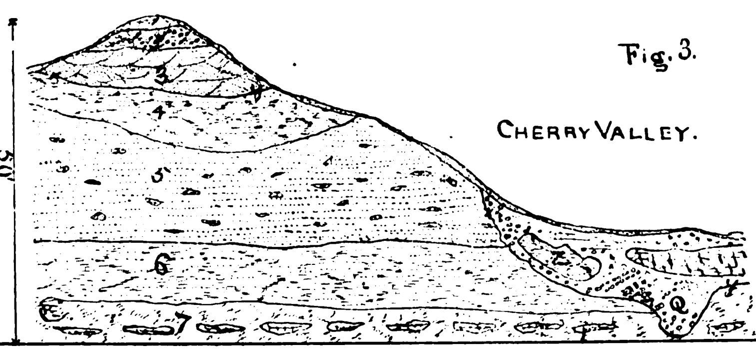


Plate VIII., Figure 1.

(For details see p. 45.)

Bluff boring at Helena.

No.		Feet.
2.	Loess, full of shells and concretions	139.2
3.	Yellowish clay	28.1
4.	Orange Sand	5.5
5.	Stiff blue Tertiary clay with Claibornian fossils	65.3

Plate VIII., Figure 2.

(For details see p. 46.)

Bottom boring at Helena.

No.		Feet.
1.	Alluvium	31.0
2.	Fine, rounded sand	56.4
3.	Coarse, clean sands, with gravel from Orange Sands.	55.3
4.	Coarse and fine sands, alternating	19.6
5.	Blue clay, with fine rounded grains of quartz	27.2
6.	Smooth blue clay, with grains of quartz; lignite in grains	16.7

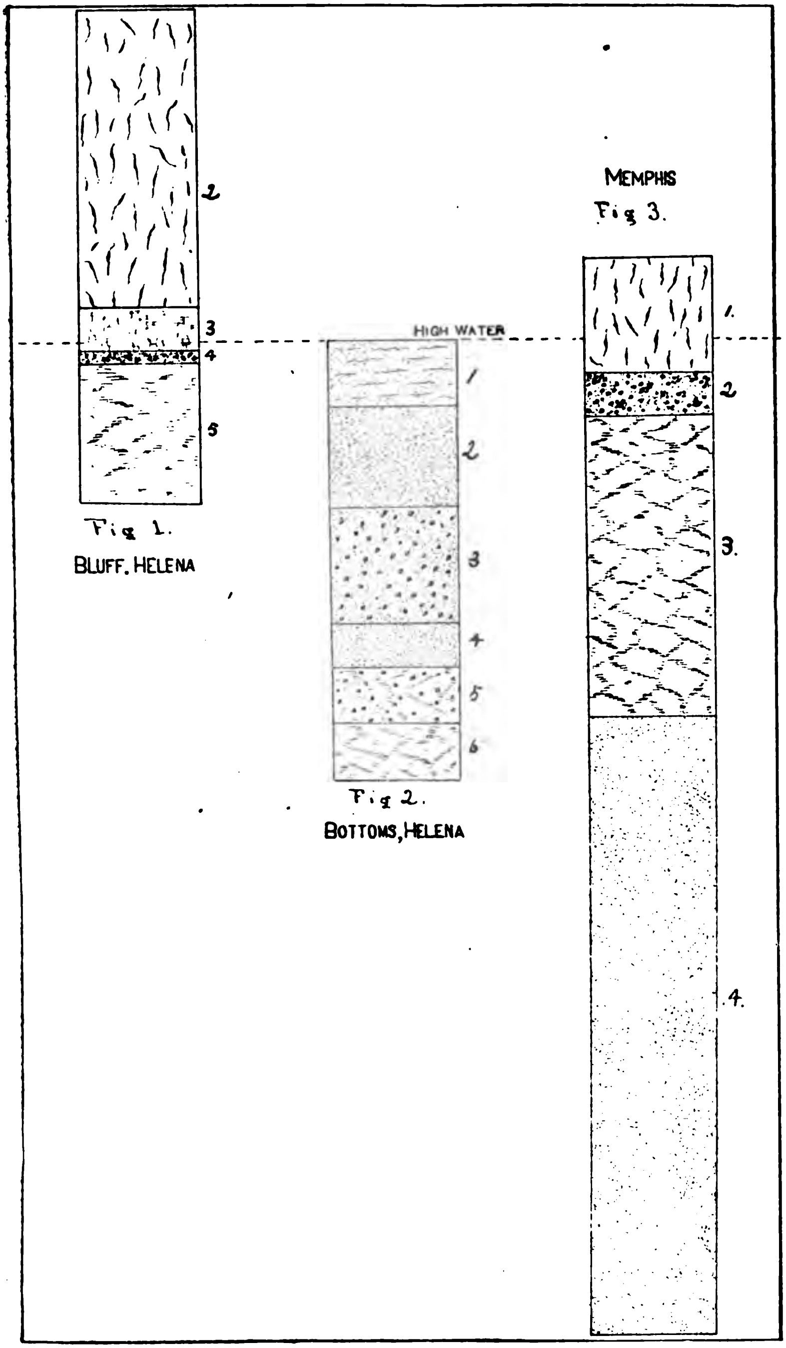
Plate VIII., Figure 3.

(For details see p. 28.)

Section of Memphis deep well.

No.		Feet.
1.	Loess	60
2.	Orange Sand and gravel; characteristic	20 to 60
3.	Dark, stiff, laminated clay, with fragments of lignite and impressions of leaves	145
4.	Water bearing sands	about 800

PLATE VIII.



MEMPHIS
Fig 3.
HIGH WATER
1
2
3
4
5
6
Fig 1.
BLUFF, HELENA
Fig 2.
BOTTOMS, HELENA

CHAPTER XXV.

ON THE RELATIONSHIP OF THE PLEISTOCENE TO THE PRE-PLEISTOCENE FORMATIONS OF CROWLEY'S RIDGE, AND ADJACENT AREAS SOUTH OF THE LIMIT OF GLACIATION.*

BY PROFESSOR R. D. SALISBURY.

The deposits made by the ice and by the waters which originated from it during the glacial period, possess a character so unique, and so markedly unlike that of the underlying formations within the glaciated area of the United States, that there has been little difficulty in discriminating between them. There have been great differences of opinion as to the relative importance of the various agencies which are believed to have been operative in the production of the drift, and in some minor measures these differences still exist. But whether the drift of any particular region be believed to be the work of glaciers or of icebergs, or of glacio-natant lakes or streams, or the joint work of two or more of these agencies, still the drift as such is clearly defined from the underlying strata. In many regions this is true no less of the valley drift which stretches beyond the glaciated area along the avenues of discharge for the melting ice, than of the unmodified drift upon the extra-valley lands further to the north, where the drift agent is believed to have been glacier ice.

But in the central part of the basin of the Mississippi River, below the latitude of glaciation, the difference between the deposits made by the waters originating in the melting ice, and the subjacent strata, appears to be much less obvious than in many other regions. In consequence, the recognition of the Pleisto-

* The substance of this chapter was prepared for publication in the American Journal of Science, and appeared under the names of President Chamberlin and myself. My measure of responsibility for the publication is there indicated, and with President Chamberlin's full knowledge and sanction, I have felt free to use in this chapter, the same phraseology, so far as it suited my purpose, over my own name. R. D. S.

cene formation along the course of the Mississippi south of the limit of the general drift sheet, and therefore the correlation of the northern and southern Pleistocene formations has not been free from difficulties. Crowley's Ridge, running from Helena northward to the northern boundary of the state and beyond, lies within the region where correlation is most difficult.

The loess.—Northern glacial drift does not exist on Crowley's Ridge at any point, nor does the northern terminus of the ridge reach the southern limit of ice action during the age of ice. Nevertheless the ridge was affected by one of the agencies operative in the glacial period. In common with the other highlands bordering the Mississippi valley, Crowley's Ridge is essentially covered with loess. With minor interruptions due to erosion subsequent to the deposition of the loess, this formation is latterly continuous with the loess which reaches northward to and beyond the southern limit of glacial drift, where the relations of the two formations are easily determinable. This continuous sheet of loess, in its relationship to the drift which underlies it at the north, and to extra-drift formations which underlie it at the south, furnishes one of the best means now at command for determining the relations between the Pleistocene and Pre-pleistocene formations in the area south of the limit of glaciation. Independently of the fact that the loess overlies the glacial drift in the southern portion of the drift-covered area of the Mississippi basin in such wise as to make the connection between the two formations an intimate one, there is, in the loess itself, inherent evidence that it is a glacier-made silt, re-worked by water. This evidence is furnished by the constitution, structure and distribution of the loess. Briefly, the evidence is this:

I. A great variety of silicates, such as the micas, feldspars, amphiboles, augite, tourmaline, epidote, etc., enter into the composition of the loess, in regions where the subjacent formation is not known to contain any of these minerals. The universal presence of magnetite and the frequent occurrence of particles of dolomite, are equally significant. These various ingredients occur in the loess much as they occur in the till, with a freshness

of surface that argues recency of origin, and that from undecomposed rock, while the form of the particles exhibits much the same angularity, and fracture faces of the same nature, in the one formation as in the other. The study of the silicates and other ingredients of the loess and till seems to necessitate the conclusion that they are closely connected in origin.

II. The loess frequently exhibits unmistakable traces of stratification, and of such stratification as water only is capable of producing.

III. It is frequently, especially in the basal portions, interlaminated with sand in such wise as to preclude the reference of its deposition to any agent except water.

IV. It occasionally carries in its basal portions, not only sand, but pebbles, derived from the underlying drift, or from pre-glacial or extra-glacial gravels, where they form its substratum.

V. It follows the courses of the valleys, and of valleys which must have served as avenues of discharge for the glacial waters, its normal facies being restricted, for the most part, to their immediate borders. These features of the loess leave no question as to its Pleistocene age. Its stratigraphic relationship to the glacial drift, would furnish further evidence, were further evidence needed, of the correctness of such reference.

The general characteristics of the loess are well known. It is best developed on the highlands immediately adjacent to the streams along which it is distributed. In such situations, the loess possesses the loose, open texture, which is one of its most definitive characteristics. As the formation is traced backward from the streams, these characteristics gradually disappear. The open texture becomes less and less pronounced, and by almost imperceptible gradations, passes from that of a loose, light loam, through that of a clayey loam, to that of a loamy clay. So far does this gradation proceed, that the texture of the loam at some distance from the streams almost wholly loses its semblance to that of the river-bluff loess.

A change in color accompanies the change in texture. The buffish color which everywhere characterizes the river-bluff loess

in its normal development, becomes deeper with increasing distance from the streams, so that along the borders of the loess where the texture has come to simulate closely that of the residuary earths, the color has become notably deeper than on the bluffs immediately fronting the river, and the deepening of the color has been a constant approximation to the color of the underlying residuary earth.

Accompanying the changes in texture and color, are changes in the chemical character of the loess. Near the rivers it almost uniformly contains a considerable percentage of carbonates. Here too it very often contains shells and concretions of calcium carbonate, the one a partial cause, and the other at once an index and a result of its calcareous character. The shells, the concretions, and the calcareous nature of the loess, are features not less characteristic, though less universal, than the texture itself. As the texture of the loess becomes closer and its color deeper with increasing distance from the rivers, the proportion of carbonates diminishes, and may entirely disappear before the border of the loess is reached. The shells and concretions are limited to the calcareous portions of the loess, or they may be still more restricted in their distribution.

With increasing distance from the streams, goes still another change in the composition of the loess: The silicates (feldspar, mica, hornblende, augite, etc.), which are found to be a very significant ingredient of the formation along the river bluffs, become less and less abundant as the other normal characteristics disappear. They may be found, however, in the loams remote from the streams, after almost every other true loess feature has disappeared.

The features thus indicated as pertaining to and defining the different facies of the loess, characterize it throughout its distribution to the north along the Mississippi and its tributaries. Throughout much of this territory, the loess lies upon the glacial drift. In southern Illinois, for example, where the glacial drift most closely approaches Crowley's Ridge, the drift for many miles north of its southern boundary is overspread with loess or with clay like loam which may be traced into direct continuity

with the normal, open textured, calcareous, shell and concretion-bearing loess, along the immediate valleys of the streams. Here too in scores and hundreds of places, especially in south-eastern Illinois, it may be seen that the surface of the drift upon which the loess rests, is one which gives no evidence of exposure to the atmosphere before the mantling loess was spread out upon it. Had such exposure found place, the fact would have left its record in the oxidation of the exposed surface, or in the accumulation upon it of an old soil, traces of which would still be found beneath the loess. But in southeastern Illinois and the adjacent parts of Indiana, no zone of oxidation and no vegetable layer or trace of old soil separates the loess from the till beneath. It would not be necessary to suppose that such a zone as that here referred to would necessarily be preserved at all points until the present time. But its universal absence over large areas, under conditions which must have been favorable for its preservation had it ever been developed, seems conclusive against the hypothesis that it ever existed. That the conditions were favorable for its preservation, is proved by *its well nigh universal presence under the loess immediately south of the drift border, in the same region.*

In many places, it may be clearly seen that the superficial loess mantle and the stony drift beneath meet each other in a thin zone of gradation. That is, the pebbles of the drift frequently occur in the basal portion of the mantling loess, in, and just above the horizon where the imbedding matrix changes from a gritty clay (till), to a gritless loam or loamy clay (loess). In other places, there is a more or less marked accumulation of drift pebbles immediately below the loess or its clayey equivalent, marking its junction with the till. Both these relationships find ready explanation in the hypothesis that glacial waters covered the till and spread out the mantle of the loess upon it, immediately after the ice retreated. And no other hypothesis seems to meet the case. In the judgment of the writer, therefore, the relationship between these two deposits, the till and the loess, as seen in almost innumerable sections, in southern Illinois and southwestern Indiana, is such as to admit of no second

interpretation as to their sequence. The loess, in the regions where such sections are found, was deposited immediately after the till, so far as not actually contemporaneous with it. The active agent concerned in the production of the loess is believed to have been water, and the material was in part derived from the till beneath, and in part from the glacial silt carried southward from the melting ice to the north. The till of the region belongs to the first glacial epoch, as we have been accustomed to distinguish epochs, and this loess *belongs to the closing stages of the same epoch, after the ice had retreated somewhat, but while the region to the south of its edge was still overspread by waters originating, in part at least, from it.

The first glacial epoch embraced at least two episodes of glaciation, separated by an interval when the climate of the southern part of the drift-covered area was so far ameliorated as to allow the growth of vegetation upon the drift of the first episode. In southeastern Illinois and the adjacent part of Indiana, the ice advance of the second episode of the first epoch seems to have been equal to it, if it did not exceed that of the first episode. This seems not to have been the case in some portions of southwestern Illinois, but in southeastern Illinois and indeed in most of the southern part of the state, the till immediately beneath the loess is referred to the second ice incursion of the first glacial epoch. The loess here under discussion is therefore to be referred to the close of the second glacial episode of the first glacial epoch. But it may be traced across the limit of the drift from north to south. The continuity is complete, and the character of the formation is the same on both sides of the line which marks the limit of ice advance. It is a continuous mantle, overspreading alike the drift border on the north, and the residuary earths which the ice did not disturb, on the south. If, therefore, the age of the loess which here covers the drift be first glacial, the age of that which lies south of the drift, in the area under discussion, is likewise first glacial.

Between the relationship of the loess to the glacial drift

*There were probably depositions of loess at various times during the glacial period whenever and wherever the necessary conditions existed.

north of the limit of glaciation, and the relationship of the loess to the residuary earths of the paleozoic rocks immediately south of the drift, there is one important difference to which reference has already been made. *The presence of a weathered and highly oxidized zone, immediately subjacent to the loess, south of the drift, is as conspicuous as is its absence to the north.* This oxidized zone is the upper surface of the residuary earths. There is, in places, a very slight admixture of residuary material and loess at the junction of the two, just as there is, in places, a slight admixture of till and loess at their junction. But the body of the residuary earth is clearly separated from that of the loess. The fact of a long interval between the loess and the residuary earths beneath, is as clearly indicated on the one hand, as is the fact of the absence of an interval between the loess and the underlying till, on the other. The phenomena on each side of the drift limit, strengthen the conclusion drawn from the phenomena on the other. Such are the relationships of the loess to the glacial drift in the locality nearest Crowley's Ridge where the two formations co-exist, and such are the relationships of the loess to the residuary earths immediately south of that region. From a consideration of these relationships where definite determinations are possible, the relationships of the corresponding formations on Crowley's Ridge, may be the more readily understood.

The loess which overspreads Crowley's Ridge, and which is fully described in the body of this report, presents all the variations known to characterize the formation. The southern portion of the ridge is very generally covered by the formation in its normal phase, and loess of the same charcter is found at intervals to the northern terminus of the ridge. But in northern Arkansas, the loess which predominates is of closer texture and of deeper color, apparently identical with the loam of southern Illinois which overspreads the highlands distant from the streams, and with the surface loam of western Tennessee and Kentucky, into which the river-bluff loess grades laterally, on recession from the streams.

So far does the loam depart from the normal loess, and so meager is its development, and so frequent its total absence on

Crowley's Ridge, in the northen portion of the state, as in the vicinity of Gainesville, that its former existence at some points can only be conjectured. Yet, even on the higher and more broken portions of the ridge, where its absence is most common, there is good reason, in the erosion remnants which still exist, for inferring its former presenee over the whole ridge. The superficial loess and loam mantle of Crowley's Ridge, like the loess and loam of adjacent regions, is clearly referable to the Pleistocene, and under the Pleistocene, to the first glacial epoch. For the sake of clearness, the classification of Pleistocene formations here adopted is appended.*

* Sixth Ann. Report U. S. Geological Survey, p. 212.

PLEISTOCENE.

Epochs.	Sub-epochs or Episodes.	Attendant or Characteristic Phenomena.
I. Transition epoch...	Not yet satisfactorily distinguished from the Pliocene.	
II. Earlier glacial epoch....................	First sub-epoch or episode........	Drift sheet with attenuated border; absence or meagreness of coarse ultramarginal drainage drift. *On Crowley's Ridge, deposition of older loess with oxidized or humus stained upper surface?*
	Interglacial sub-epoch or episode of deglaciation...............	Decomposition, oxidation, ferrugination; vegetal accumulation. *On the Ridge, erosion of loess, and of subloessial gravel, and deposition of same at lower levels.*
	Second sub-epoch or episode.....	Drift sheet with attenuated border; loess contemporaneous with closing stage. *On the Ridge, deposition of the main (upper) body of loess.*
III. Chief interglacial epoch..............	....	Elevation of the Upper Mississippi region 1,000 feet. Erosion of old drift, decomposition, oxidation, ferrugination, vegetal accumulations. *On the Ridge, erosion of loess and of subloessial gravels and accumulation of same at bases of slopes. Deepening of valley depressions surrounding the Ridge.*
VI. Later glacial epoch....................	First episode or sub-epoch........	Till sheet bordered by the Kettle or Altamont moraine.
	Episode of deglaciation.............	Vegetal deposits.
	Second stage of sub-epoch.........	Till sheet bordered by the Gary moraine.
	Episode of deglaciation.	
	Third episode..........................	Till bordered by the Antelope moraine.
	Later stages.............................	Marked by terminal moraines of undetermined importance.
	On Crowley's Ridge, during the whole of the second (later) glacial epoch, erosion of loess and of sub-loessial sand and gravel; filling of valleys surrounding the Ridge with glacial sands and silts.	
V. Champlain epoch.	....	Marine deposition in the Champlain and St. Lawrence valleys, and on Atlantic border; lacustrine deposits about the great lakes. *In Arkansas same work as in second glacial epoch.*
VI. Terrace epoch....	....	Marked by fluvial excavation, notably of the flood plains of second glacial epoch.

There is no manifest reason in the nature of the case, why the making of loess should not have accompanied and followed the ice action of the first episode of the first glacial epoch, just as it accompanied and followed the second episode. Were this the fact, there should be a two-fold division of the loess south of the drift. Such division was anticipated and has been diligently sought, but with negative results so far as most of the extra-drift loess-covered area is concerned. At several points on Crowley's Ridge however, there are indications that the division here suggested actually obtains. In some places this indication consists in the presence of a thin layer of loam, apparently humus-stained, between two layers of loess. In the railway cuts east of Forrest City, such a layer may be seen at various points. It is covered by a layer of loess of variable thickness, in places reaching 15 feet at least, while below it there is another layer of loess, somewhat unlike that above, and showing unmistakable signs of stratification. The humus-stained layer is 2 to 4 feet in thickness, is sharply limited above, but below graduates insensibly into the underlying material. At Memphis, Tenn., there are similar indications of a two-fold division of the loess.

At other points on the ridge, as near Gainesville, Jonesboro, and at points north of Forrest City, as also in the vicinity of Dexter, Mo., a more or less distinct zone of weathering and oxidation may be observed between layers of loess or of loam which is correlated with the loess. This oxidized (reddish) zone in the loess is best marked above, and fades out gradually below. Its thickness is never great. Four to six feet beneath the surface few traces of oxidation remain, and such traces are often limited to half that depth. Lack of correspondence of the material above and below, is however common. Professor Call directs attention to the fact that loess on different parts of the ridge possesses different characteristics. If we are rightly informed, Professor Call has suggested a two-fold division of the loess on the basis of these differences, and on the basis of the different distribution of the different types; but so far as we are aware, he does not suggest a subdivision on the basis here indicated, or a subdivision which involves the sequence of events here suggested. The

question is here raised whether his two-fold division of the loess may not find its explanation along the lines here indicated.

The gravels and sands beneath the loess. ("Orange Sand.")—Concerning the formations which lie beneath the loess, there has been great diversity of opinion. The gravels and sands which make up a considerable part of Crowley's Ridge are regarded as identical with gravels and sands of the southernmost counties of Illinois, of southeastern Missouri, and of western Kentucky and Tennessee. These gravels and sands have been regarded as Tertiary by the Illinois geologists, and as Quarternary by the geologist of Kentucky and Tennessee* and also by Professor Hilgard. The character of the gravel and sand is described by Professor Call in the preceding pages, and for details concerning the same the reader is referred to these descriptions.

The writer has seen the loess and the underlying gravels and sands in their relationship to each other throughout the larger portions of the areas where they occur, in Missouri, Illinois, Kentucky, Tennessee, and at many points in Arkansas, and has reached the conclusion that these gravels and sands, with but minor exceptions, do not belong to the Pleistocene. Upon the question of the classification of Pre-pleistocene formations I purposely do not enter. Whether any particular portion of the gravels and sands and clays which underlie the loess be late Pliocene, or middle Pliocene, or early Pliocene, or not Pliocene at all, is a question which belongs to those who are experts in the classification of the Tertiary formations. The first glacial epoch is regarded as marking the inauguration of the Pleistocene. Since this period first made itself felt to the north, the Pleistocene may, in some proper sense, be said to have begun at the north earlier than at the south. Without at all insisting that every formation antedating the ice incursion at any particular latitude shall be ruled out of the Pleistocene, there are several considerations which have led the writer to regard all the forma-

* The Orange Sand of Safford is regarded by him as Tertiary, while the bluff gravels, which are are the equivalent of the Orange Sands of Hilgard, are regarded as Quarternary. The bluff gravels of Safford are represented on Crowley's Ridge. As to the existence of the Orange Sand or Lagrange formations of Safford upon the Ridge, we express no opinion.

tions of Crowley's Ridge beneath the loess as Pre-pleistocene. All the upland formations of southern Illinois, of western Tennessee, and Kentucky, and of southeastern Missouri, underneath the loess, are likewise regarded as Pre-pleistocene.

These considerations are as follows: 1.—*The unconformity which exists between the loess and the underlying gravels and sands.* The loess of Crowley's Ridge, as likewise the loess of all the area in adjacent states where the formation overlies similar gravels and sands, constitutes a mantle that covers ridge crests and ridge slopes indiscriminately. The gravel which commonly constitutes the immediate substratum of the loess, is often to be found on the slopes of the ridges, as well as on their crests. But in many localities in Arkansas, and adjacent states where the formations and their relationships are essentially the same, the slope gravels are evidently nothing more than talus formations. In such cases the talus gravels of the slopes evidently descended from the gravels of the higher levels of the hills and ridges, in the ordinary processes of subaerial erosion.

Beneath the capping gravel, there are commonly heavy beds of highly colored sand. Associated with the talus gravels there is generally more or less debris arising from indurated laminæ, or even considerable layers of this sand which lies below the gravel. The eroded edges of such laminæ of sandstone, are frequently exposed in the gulleys and ravines of the slopes. These erosion and talus-strewn slopes, as well as the crests of the hills and ridges, are mantled with loess. It will be readily seen, therefore, that the relationship of the loess to the subjacent formations points to the conclusion that the latter had suffered erosion, and somewhat extensive erosion, before the depositions of the loess. This unconformity is more strikingly shown in some localities in adjacent states, than in any sections seen by the writer on Crowley's Ridge, but the general relationship of the loess to the underlying formation, is such as to make necessary the inference of general unconformity between the two, even though the line of unconformity be not frequently exposed.

So far as the mere fact of pre-loessial erosion of the gravels and sands is concerned, they might belong to a stage of the Pleis-

tocene previous to that of the loess, in case the loess belongs wholly to the second episode of the first glacial epoch. But when the extent of the erosion is considered, which intervened in some localities between the deposition of the gravel and that of the loess, it is necessary to allow for a long interval for the accomplishment of observed results. Furthermore, this hypothesis will not stand if there be loess belonging to the first glacial episode, as seems to be indicated by the subdivision of the loess above noted, resting unconformably upon the gravels. In this case allowance must be made for the subaerial erosion of the gravel before the first episode of the first glacial epoch. The observed amount of erosion suffered by the gravel and sand prior to the deposition of the loess, if it occurred before the first episode of ice action, would seem to us to throw the deposition of the gravel necessarily into the Pre-pleistocene. The only question of doubt is as to the reference of loess to the first glacial episode. The probabilities in favor of the correctness of such reference have already been cited.

Again, it is altogether irrational to suppose that the gravels which (under the loess) cap Crowley's Ridge were deposited upon the ridge as such. Had the ridge existed as a ridge before the deposition of the gravels, it would seem necessary to suppose that the low land on either side must have first been filled up essentially to the level of the ridge, thus destroying its character as a ridge before the gravels could have been deposited. On the other hand, from the disposition of the loess it is believed that Crowley's Ridge was defined before the loess was deposited.* There is no independent evidence that such an amount of erosion as the isolation of Crowley's Ridge would involve took place between the first and second episode of the first glacial epoch, although conclusive evidence to the contrary can not be said to

* The extent of the pre-loessial definition is, to my mind, still an open question. If the depressions surrounding the ridge were less deep than now, at the time of the deposition of the loess, it would seem necessary to suppose that the post-loessial deepening of these depressions was accompanied and followed by wash and creep of the plastic loess down slope to such an extent as to keep the slopes essentially covered to their bases. There is good evidence that these slope movements of the loess have occurred; but I am by no means ready to urge that they have taken place on such a scale as the above suggestion would indicate.

be at hand. This line of evidence, therefore, emphasizes the conclusion already reached, that the pre-loessial erosion of the gravel and sand formation of Crowley's Ridge was considerable, and therefore that the time involved was long.

Unconformity between the loess and the formation below is not everywhere apparent, and where apparent, is not everywhere great. The attitude of the land during the interval between the making of the two formations appears not to have been such, in all localities, as to favor erosion. In Mississippi the formations are said to be conformable with one another. In the southermost counties of Illinois the unconformity is greatest.

2. A second consideration which has led to the Pre-pleistocene reference of all the formations inferior to the loess, is the *profound weathering and oxidation which these formations underwent previous to the deposition of the loess.*

Although the lapse of time since the closing stage of the first glacial epoch is great, the loess does not seem to have undergone any considerable alteration in chemical character since its deposition. Its surface for a depth of from four to six feet often shows unmistakable signs of oxidation and weathering. Locally, oxidation has penetrated to greater depths. The particles of the surface portion have been disintegrated by chemical and physical means, so that they have become notably finer than they were at the time of their deposition, and finer than those of the lower portion at the same locality. Were another sheet of loess to be spread over the first today, the distinction between the two in later times would be perfectly clear, on account of chemical and physical changes which the present loess has suffered in its superficial parts. Yet even this distinction would be far less conspicuous than that which now exists between the loess and the surface of the underlying material. This comparison may be in some sense unfair, since it is true that the substratum of the loess and the loess itself are inherently dissimilar; but it is not this difference which is here insisted on. It is the degree of alteration which the surface of the material below the loess has suffered—an alteration such as surface exposure would effect—which is of significance, and this alteration, which must have

taken place before the deposition of the loess, is estimated to be greater than that which the surface of the loess has undergone since the close of the first glacial epoch.

In many places there is a thin layer (from four to eight feet) of earth above the gravels which underlie the loess. This is believed to represent, at least in many places, the last work of the waters which deposited the coarser material below. It is commonly somewhat gritty, the gritty element (sand) partaking of the nature of the sand below, but it is distinctly earthy in texture. The textural difference between it and the loess is much less than that between the loess and the upper surface of the Orange Sands as commonly developed, but quite as great as that between the loess and the till. But it is in just such situations that the line marking the junction of the loess and the underlying earth is most conspicuous and significant. The latter shows the texture and deep coloration which denote the oxidation and surface alteration which result from long exposure to atmospheric action. In many places, the junction of the loess with this layer is the most obtrusive line in the section. In more than one place, it may be noted in passing, does this super-gravel earth show an eroded surface, upon which the loess rests unconformably, though the degree of unconformity in such cases is often slight.

The chemical changes in the sands and gravels are not confined to their surface. Beneath the surface, and so far beneath it as to be below the zone of active surface weathering, there is evidence that great changes have taken place, denoting the lapse of long intervals of time. The most obvious of these changes is the extent to which the leaching and concentration of coloring matter have been carried Besides this, there are various other changes less clearly defined, but which, in the aggregate, give to the whole series below the loess an appearance of age which is unmistakable. The changes which the Orange Sand formation has undergone since its deposition certainly appear to be several times as great as those which the loess has suffered since its deposition. Taken by itself this might not be a safe standard for

chronological measurements, but it has a strong corroborative significance, since it falls into correspondence with conclusions drawn from other lines of evidence.

Outside the drift region, the material underlying the loess is often residuary earth derived from paleozoic rock instead of from Orange Sand. So far as oxidation and the changes induced by exposure are concerned, the residuary earths from the paleozoic rocks do not seem notably more affected than those from the Orange Sands. This is but an eye estimate, and may be erroneous, quantitatively considered, though it is based on the observation of many hundreds of sections. But in any case, the fact of profound affection of the pre-loessial surface by atmospheric agencies in pre-loessial times, is believed to be beyond dispute. And this is no isolated phenomenon. Generally speaking, it holds throughout the length and breadth of the extra-drift loess territory within the limits of the writer's observation, and by report much beyond. The depth and extent of this weathering of the pre-loessial surface, is incomparably greater than that of the surface already alluded to as possibly marking the surface of an earlier (first glacial episode) loess. On this point Professor Hilgard writes: *

"The Orange Sand, as a rule, contains nothing that is capable of further oxidation or solution by atmospheric agencies, unless it be silex. Such complete preoxidation and lixiviation, the effects of which have largely extended into underlying formations, unquestionably indicates a long subaerial exposure, from which the northwestern stratified drift was in a great measure exempt." Dr. Loughridge likewise† recognizes the presence of "a bed more clayey and darker (than the loess) in color" between the loess and the Orange Sand at Hickman, Ky., and "4 feet of the stiff, darker loam" below the loess and above the gravel at Columbus, Ky. These

* Am. Jour. Sci., 1872, Vol. 4, p. 266. The same point is repeatedly insisted on by Professor Hilgard in other articles in this journal, and in his report on the Agriculture and Geology of Mississippi.

† Kentucky Geological Survey, Jackson Purchase. Region, F.—1888, page 78.

"darker loams" represent the oxidized materials of the pre-loessial surface, as we interpret the phenomena, and are to be sharply discriminated from the loess, with which, except in the matter of position, they have nothing to do. We fully concur with Professor Hilgard in his conclusion that this material "unquestionably indicates a long subaerial exposure," before the deposition of the loess.

From the relative position of loess and Orange Sand, it is evident that the latter is the older. From the stratigraphic relations of the two formations, it is equally evident that the depositions of the former followed that of the latter, only after a considerable interval of time. The chemical changes which the older formation has suffered, strengthen the conclusion drawn from the unconformity, that this interval was long.

3. *The constitution of the gravels of Crowley's Ridge, precludes their reference to the Pleistocene.*—Reasons have been adduced for referring the gravels which constitute the latest portion of the sub-loessial series, to the period antedating by a long interval, the loess itself. If these reasons cannot be regarded as absolutely conclusive against the correlation of these gravels with the first episode of the first glacial epoch, the constitution of the gravels themselves, with all that it involves, seems to leave no doubt on this point.

The gravels of Crowley's Ridge are, in all characteristics which are essential to the present discussion, like those of western Kentucky and Tennessee, like those of southern Illinois, and southeastern Missouri. There are minor differences in their constitution, dependent on the differences of the rocks from which they are derived, but these are not especially significant, so far as the question of the age of the gravels is concerned. It is to be noted that the gravels of southern Illinois, of southeastern Missouri, of western Tennessee and Kentucky, as well as those of Crowley's Ridge, occupy a geographic position which makes it necessary to suppose that the drainage of the ice of the first episode passed through the region which they occupy. If these gravels date from this time, they should contain pebbles of northern

drift. It would not be necessary to suppose that all the gravel deposited by a stream springing from the glacier would necessarily be northern, since extra-glacial tributaries might bring in material from extra-glacial sources, in the ordinary process of river degradation. But emphasize the importance of this latter consideration as we may, it yet remains an indisputable fact, that, were the conditions of drainage such that tributaries could bring gravel to their main in great quantities, the main itself, if springing from the ice, would inevitably bring something of glacial debris, which would be found mixed with the material of more local origin, which the tributaries might have brought in. And this would be true, even if the accumulation of the gravels took place at an early stage of the glaciation of the first episode, long before the ice approached the latitudes under consideration; for the drainage basin of the Mississippi reaches several hundreds of miles to the northward, and probably extended still further in that direction, at an early stage of the ice invasion, when the ice had so far spread itself over the British Possessions as to prevent drainage into Hudson's Bay.

If then the Orange Sands and gravels were accumulated during the first glaciation of the first glacial epoch, as valley or estuary deposits, we should of necessity have northern material a constituent of these sands and gravels. Such, however, is not the fact. In the hundreds of exposures of gravel which the writer has seen, large numbers of which, in various localities in Arkansas and in the other states already named, have been examined in detail for this especial purpose, not a single pebble of demonstrably northern origin, has ever been found. Northern pebbles have been found associated with pebbles derived from the gravels under consideration, but only in such situations that the secondary character of the deposits containing such pebbles, was certain, or altogether probable, from considerations entirely independent of those here noted. And the freedom from northern gravel and sand does not characterize the Orange Sands simply in their more southern distribution, where the local

material might naturally be more abundant than to the north, but even up to the northern limit of the Orange Sand regions, scarcely more than a score of miles from the southern border of the glacial drift, the northern pebbles are likewise altogether absent. And it is not simply glacial pebbles which are wanting. The absence of glacial sand and silt from the Orange Sand formation is equally conspicuous and significant.

If there be on Crowley's Ridge an older loess, dating from the first episode of the first glacial epoch, as the writer is inclined to believe, the argument might rest at this point, for the gravel could not have antedated the loess (to say nothing of the long interval of weathering and erosion between the two), and still be Pleistocene, except by being contemporaneous with the earlier stages of ice action in the first glacial episode. That the Orange Sand could not have been contemporaneous with the ice action of the first glacial episode, is clearly indicated by the evidence already adduced.

But if the evidence of two loess episodes be not deemed conclusive, it might be suggested that the gravels date from the interval between the two glaciations of the first glacial epoch, and so from a time when the streams did not carry glacial waters. In this event, the gravels would be older than the loess, if that belongs entirely to the second episode of glaciation. But this hypothesis is in no way better than the other, so far as the Pleistocene reference of the gravels is concerned. For, on this hypothesis, even if the Mississippi did not carry glacial waters at the time of the deposition of the sand and gravel, it was nevertheless coursing through a basin covered with drift, and this drift must certainly have yielded its contribution to the river gravels, for by hypothesis, the conditions of drainage were such as to allow the rivers to transport gravel and sand. The only escape from this conclusion would be to suppose that neither the Mississippi nor its tributaries north of the limit of drift had power to transport sand and gravel and that both the Missis-

sippi and its tributaries south of the drift limit had such power.

But it is incredible that there could have been drainage conditions up to within twenty-five miles of the edge of the ice, or up to within twenty-five miles of the drift sheet, if the ice had retired, such that enormous quantities of gravel could have been brought in by the tributaries from right and left, and carried down by the Mississippi. well toward the Gulf of Mexico, while the Mississippi, just above that point where current velocities necessary to the above work existed, should be so sluggish as to bring down, so far as present knowledge goes, nothing whatsoever of glacial silt or sand or gravel from the north. If the main stream were strong enough to carry forward the gravel of its extra-drift tributaries, (and it certainly was, if the Orange Gravel be river gravel at all, or if it were ever transported through the Mississippi valley), it would in all likelihood be strong enough to erode above those tributaries, and the material which it brought down from its intra-drift course would be admixed with that contributed by the extra-drift tributaries. If then the Orange Gravels be river gravels, and if drift existed in the Mississippi basin when they were deposited, even though the ice had wholly retreated from the same, so that no glacial waters coursed through the valley, such drift must certainly have yielded a contribution of gravel and sand to the Mississippi, both directly and through tributaries, at the same time that the tributaries south of the drift limit were making their contributions of sand and gravel. In this case, as in the other, there would necessarily be northern material in the gravel. The freedom of the Orange Sands from all northern material seems, therefore, altogether conclusive against its reference to the time of the first glaciation, or to any time subsequent to the first glaciation.

Statements have been made concerning the constitution of the Orange Sand gravels which are quite at variance with our own. By implication at least, all geologists who have re-

ferred them to the Champlain epoch* assign them a northern origin, and Professor Hilgard thinks the difference between the Orange Sand formation and the northern drift, "quantitative rather than qualitative," and that the materials of the two "are essentially correspondent."†

If the gravels and sands of Crowley's Ridge, under first glacial loess be fatal to their reference to the Champlain epoch, and if their unconformity with the loess, and their "perfect peroxidation" antecedent to the deposition of the loess be fatal to their reference to the epoch immediately preceding that of the loess, no less does the complete absence of glacial material from the sands and gravels preclude their reference to any stage of the first ice epoch, or to any period subsequent to the first ice invasion. We are therefore shut up to the conclusion that the Orange Sands are Pre-pleistocene. And even if an occasional northern Archæan pebble should hereafter be found in the Orange Sand, we should not, on the strength of this evidence alone, regard our conclusion as invalidated; for the drainage basin of the Mississippi reaches well back into the area of Archæan rocks, and it would not be at all surprising if Archæan pebbles from this source should have found their way into the lower Mississippi valley before the glacial period.‡

It may be an open question whether the formations below the loess in the region under consideration immediately preceded the Pleistocene, but it is not the purpose of this chapter to discuss that question. It is pertinent to the subject here discussed, however, to remark that the conditions of drainage dur-

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* Hilgard; Agriculture and Geology of Mississippi, 1860, and Am. Jour. Sci., 1866, Vol. 41, p. 311.

Safford: Am. Jour. Sci., 1864, Vol. 37, p. 361.

Dana, J. D.: Manual of Geology, 3d Edition, p. 548.

Le Conte. Elements of Geology, p. 548.

Loughridge: Jackson Purchase Region, Kentucky Geol. Surv., 1888.

† Am. Jour Sci., 1866, Vol. 41, pp. 313 and 315.

‡ Hilgard says (Am. Jour. Sci., 1866, Vol. 41, page 318), that there have been found "rare and well worn pebbles of greenstone, porphyry, trappean rock, and even mica schist, * * * among the shingle of the Mississippi band," and raises the question whether they may not have originated from Arkansas. Considering the absence of such material in the gravels of the Orange Sand formation further north, this hypothesis seems plausible.

ing the first glacial epoch were such as to produce only sluggish currents so far as now known. But the Orange Sands, whether of fluvial or estuarian origin, date from a time when drainage conditions were such as to allow the rivers to bring in large quantities of gravel, and often of very coarse gravel, from widely separate sources. It is therefore manifest that the attitude of the country in the Orange Sand region must have been very different in the Orange Sand and glacial epochs, and the shifting of attitudes to match the drainage conditions of these two epochs, may have involved a considerable lapse of time.

In the light of the foregoing evidence, we find but one conclusion possible respecting the age of the Orange Sand. In six states, at least, it is true that beneath the loess and above the Orange Sand there is an old surface so deeply weathered and oxidized as to indicate a long period of exposure before the deposition of the loess. Occasionally this old surface is humus-stained, indicating the growth of vegetation upon it, before the subsequent formation was made. Between this weathered and oxidized or humus-stained surface and the loess, there is wide-spread and often striking stratigraphic unconformity. Everywhere below this horizon, which is clearly recognizable in nearly every one of the thousands of large and small exposures seen by the writer, there is an absence of material which can be referred to a glacial origin, while above this horizon, the loess and other fluvial deposits contain material of glacial derivation. *This old surface, this horizon of oxidation, weathering, erosion; this horizon below which glacially derived materials do not occur, and above which they are present, we hold to be the dividing line between the Pleistocene and the Pre-pleistocene formations.*

Thus far no mention has been made of certain beds of gravel which have given rise to more or less misinterpretation. So soon as the gravels of the Orange Sand series were elevated above the waters which deposited them, their degredation began. From these Pre-pleistocene gravels, materials have been eroded and redeposited throughout the course of Pleistocene time. These processes were operative during the Pleistocene age before the loess was deposited, as well as at the time of loess deposition

and subsequent thereto. Under the circumstances it necessarily follows that there must be beds of gravel derived from Pre-pleistocene formations in Pleistocene time. During the deposition of the first loess, and especially during the earlier stages of the same, pebbles derived from the Pleistocene beds of the higher levels were mingled with the loess then being deposited on the lower. As the loess-depositing waters rose, pebbles of the higher levels became involved in the basal portions of the loess deposited on these levels. Thus arose, in the opinion of the writer, some of the beds of loess on Crowley's Ridge, in the basal portions of which pebbles occur. So soon as a mantle of loess covered the hills and ridges, further contributions of gravel would cease, and the loess subsequently deposited would be free from pebbles. That the pebbles of the loess are confined to its basal portions, as this hypothesis requires, is a matter of common observation.

Again, if there were two epochs of loess deposition on Crowley's Ridge, as seems very probable, erosion took place on a more or less extensive scale during the interval between them. The earlier loess may have been completely removed in places, baring the gravels below. These gravels would then have yielded a talus of gravel stretching down slopes, and over areas where the loess had not been removed. In this manner, it is believed, the scattering pebbles, or even thin seams of gravel which are occasionally found between an upper and lower loess, are to be explained. It is worthy of note that where pebbles occupy such a position, the upper surface of the loess below them commonly shows signs of weathering, a fact altogether consistent with the above explanation.

Still later, in post-loessial times, loess has been carried down the slopes on which it was originally deposited. In many places the whole body of loess has been removed, so that meteoric waters are again working upon the underlying gravels, and carrying them down slope, mingling them with the loess carried down by the same means, at the same time. In these several ways, it is believed, has occurred so much of intermixture, and so much of interstratification of gravels and loess, as exist. It may well be

that landslips have also added to the observed complications between two formations. Yet with all these possibilities of intermixture and interstratification, the amount of the same is small, not greater than might have been expected, antecedently. It is needless to add that none of the beds of gravel belonging to this category, are here referred to the Pre-pleistocene series. None of them belong to the Orange Sand of Hilgard or to the Bluff Gravels of Safford, if we understand aright the limitations imposed upon these terms, by the geologists who first used them.

The second glacial epoch is not believed to be represented by any formation on Crowley's Ridge. Borings in the Mississippi flat on the eastern border of Arkansas, show that there is a very considerable filling of relatively recent material, and therefore that the river now flows at a higher level than at an earlier stage in its history. If this flat be traced northward, it is found that, somewhere below the mouth of the Missouri, remnants of a sand terrace emerge from the plain. * If these terrace remnants be followed up stream, they are found to rise higher and higher, and at the same time their constitution becomes coarser and coarser, until at the head of the terrace, the material is coarse gravel.

The terraces of the Mississippi valley are matched by the terraces of innumerable streams heading within the area of second glacial drift, throughout the extent of the territory covered by second glacial ice. *These terraces head in the moraines of the second glacial epoch,* and represent the floodplain deposits of the streams which discharged the waters of the ice of the second glacial episode. Their position and their constitution leave no question as to their second glacial reference, and they are believed to be the only representative of the second glacial epoch beyond the limit of second glacial ice, except such deposits as may have been made by lakes fringing the ice, and except the overwash plains of glacial debris made by temporary currents in the vicinity of the ice-edge.

The terraces decline southward, as already indicated, and the

* The exact parallel at which this terrace first appears above the flood plain is not known. The southernmost point at which it has been observed by the writer, is a short distance north of Cape Girardeau, Mo., and there only a remnant in a tributary valley.

general tenor of present observation points to the conclusion that they disappear beneath the modern flood plain in the Mississippi valley, before the latitude of Arkansas is reached. If so, their southward extension is buried in the present valley bottom, and here must be sought whatever of debris from second glacial waters there may be in Arkansas. There are, however, certain river plains of limited elevation. above the present bottoms, south of the latitude where second glacial terraces have been identified, which give some ground for suspecting that they belong to this age.

CHAPTER XXVI.

DESCRIPTION OF FOSSIL WOODS AND LIGNITES FROM ARKANSAS,

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The material upon which the present paper is based consists of a small collection, numbering about twenty specimens, obtained during the field season of 1889, by Professor R. Ellsworth Call, of the Arkansas Geological Survey in the northeastern part of the state.

Of the material collected, the lignites, without exception, come from the clay beds of the Eocene Tertiary. These beds underlie a party-colored, cross-bedded series of sand beds of probable Tertiary age. The lignites occur in no other position. In the majority of cases they come from massive beds several feet in thickness, but in the cases of the best preserved specimens, in point of structure, they come from masses of a few inches to several feet in length scattered at various irregular localities in the clay beds.

The silicified woods are all from the sands or gravel beds which overlie the Tertiary clays above mentioned. In most cases the material was taken in place, but in one or two instances noticed in connection with the detailed descriptions below, the specimens come from the beds of streams, but under circumstances which render it absolutely certain that they were originally derived from the circumjacent deposits of Orange Sand.

Following is a list of the localities with the field number of the collector:

LIGNITES.

5. Bolivar Creek, Poinsett county, in 11 N., 4 E., section 7. This sample is from a stump in place in the drab fire-clays

underlying the lignite bed at the base of the section on the south bank of the creek, and near the bed of the stream.

6. Lignite bed on the Butler farm in the southwest part of Clay county, and seven miles north of Gainesville, Greene county.
7. From the Eocene clays on Little Crow Creek, St. Francis county; 5 N., 3 E., section 35.

   The samples of lignite occur as scattered masses of lignitized wood at numerous points in the section along this creek, but always below the sands of Tertiary age which overlie the clay beds. In some instances the specimens weigh many pounds, in others the fragments are very small.
8. Locality the same as no. 7.
11. Locality the same as no. 7.
12. Locality the same as no. 7.
13. Bolivar Creek, Poinsett county, 11 N., 4 E., section 8, the northwest quarter of the southwest quarter. The sample is from the lignite bed on the south side of the creek. This lignite is about 7 feet thick, and outcrops a few hundred feet below the locality of no. 5 above. It breaks from the cliff in cubic masses of many pounds weight, but soon crumbles to powder under atmospheric influences.
14. Locality the same as no. 7.

SILICIFIED WOODS.

1. From the Orange Sand gravels near their base, Bolivar Creek, Poinsett county, 11 N., 4 E., section 8, the northwest quarter of the southwest quarter. The specimen is from a mass of several cubic feet.
2. From the bed of Rice Branch, on Spanish Grant 239 near Wittsburg, Cross county. Derived from the adjacent Orange Sand gravels.

2a. Bed of Rice Branch on Spanish Grant 239 near Wittsburg, Cross county. From the trunk of a tree near its base, a mass of 4 or 5 tons, derived from the Orange Sand gravels; it was found partially buried in the gravels.

3. Bed of Rice Branch, the same place as no. 2a, near Wittsburg, Cross county.
4. From the Orange Sand gravels on Little and Big Crow Creeks, St. Francis county, section 36, 5 N., 3 E. This specimen is from a gravel bed traced continuously from the one stream to the other; the equivalency of which is unquestionable. Numerous pieces occur in the bed of the stream and in the gravel bed in the face of the cliff.
9. From the base of Red Bluff on the south side of the Arkansas River, Jefferson county. The specimen was derived from the Orange Sands capping the higher lands a mile or two south of the river.
10. This specimen is unique in having been taken from a large stump in place in the clays of Eocene age, five and a half miles northwest of Gainesville, Greene county. The sands and gravels which cap the Tertiary clays in the region have been entirely eroded away and left the stump thus exposed standing in place.

SYSTEMATIC DESCRIPTION.

LIGNITES.

To the naked eye the various pieces of lignite present all the characteristics of wood that are usually to be observed in material of this kind, and seem to have been very well preserved, but when examined under the microscope it is found that they have been much distorted by pressure and the various agencies of decay and disintegration. But by making numerous sections and selecting points that have been exceptionally well preserved,* a fairly clear idea of the original structure may be worked out. With the exception of numbers 12 and 13, it is all coniferous, and so far as it is possible to decide from the distorted structure, seems to belong to the genus *Cupressinoxylon*.

Number 7, from the Tertiary clays underlying the Orange

* For description of the methods employed in the examination of lignite, see "Fossil Wood and Lignite of the Potomac Formation," by F. H. Knowlton. Bull. 56 U. S. Geological Survey, pp. 40, 41.

Sand gravels on Little Crow Creek. The first slide shows several pieces with moderately well preserved structure, in one particularly well preserved spot, there being several cells exhibiting the characteristic bordered pits. They are arranged in a single longitudinal row in the center of each cell. The second slide also shows several cells with the single row of pits and the third slide settles beyond question its coniferous nature. The bordered pits are always small and in a single row.

It was impossible to determine precisely either the structure of the medullary rays or the structure of the tracheids in transverse section.

This material bears considerable resemblance to *Cupressinoxylon arkansanum*, which is described as new on p. 253, Pl. IX., Figs. 1, 2, from a silicified specimen (no. 2a from Rice Branch), but as stated above, it is impossible to make out all of the characters of this specimen of lignite, and consequently the resemblance may be only superficial.

Number 8, from the same locality as no. 7. It is evidently the same and from the same geologic horizon, but is not as well preserved.

Number 5, from Bolivar Creek, is also clearly coniferous. The bordered pits are smaller than in numbers 7 and 8 and are frequently arranged in two or more longitudinal rows. As in the other cases it was impossible to make out the structure of the medullary rays.

Number 6, from Butler farm near Gainesville, Greene county, is too poorly preserved to admit of determination.

Number 11, St. Francis county, from the blue stratified Tertiary clays underlying the Orange Sands. The same as no. 14. Very poorly preserved.

Number 14, from the same locality as no. 11. This material is poorly preserved and the structure is made out with difficulty, but it can hardly be other than coniferous. The medullary rays are arranged in a single series of less than twenty superimposed cells. It was impossible to make out the bordered pits in any instance. In general appearance this is not greatly unlike some of the material described

from silicified specimens, but this can be regarded as little more than conjecture.

Number 12, St. Francis county. This is the same as no. 13 but not as distinct.

Number 13, from the lignite bed on the south side of Bolivar Creek, 11 N., 4 E., section 8, northwest quarter of the southwest quarter. The lignite is about seven feet thick. See p. 81. This is clearly dicotyledonous. The macroscopic appearance is at once suggestive of it and the microscopic examination abundantly confirms it. The medullary rays are usually in two series of superimposed cells, or a few with only one. The ducts are relatively large and pitted as in some of the silicified specimens from Rice Branch near Wittsburg. (See Pl. IX., Figs. 8, 9.) So far as as can be determined from the material it is the same, or least very similar to what has been described from the silicified material as *Laurinoxylon branneri*.

SILICIFIED WOODS.

This material is thoroughly silicified, and is, in general, very well preserved and admits of careful study. Most of the specimens are rather small and occurred as scattered pieces in the various strata from which they came, although one (No. 2a) was from a mass of four or five tons in weight.

CONIFEROUS.

Cupressinoxylon arkansanum, n. sp.
Plate I., Figs. 1, 2.

Description.

Annual ring not distinguishable; tracheids moderately thick walled with a single row of bordered pits; medullary rays from 2 to 22 cells high, of a single, or rarely in the middle of the ray, of two tiers of cells; resin tubes moderately numerous.

Collection number 2a, from bed of Rice Branch, near Wittsburg, Cross county, Arkansas. This specimen, as stated above, is a mass of four or five tons in weight. It is

completely silicified and is yellowish in color. The structure is not very well preserved, it being difficult to make out some of the important characters.

Transverse section.—The annual ring is either entirely absent or so obscured by the mass of crushed cells as to be indistinguishable. In a single exceptionally well preserved spot the tracheids are seen to be arranged in nearly uniform radial rows (Pl. IX., Fig. 2), there being generally about three or four rows between two medullary rays. The rays are abundant and consist of a single cell.

Radial section.—The tracheids are rather thick walled and provided with a single row of pits. The pits are rather distant, the outer circle having a diameter of from .011 mm. to .0145 mm. and the inner a diameter of from .0028 mm. to 0048 mm. The medullary rays are abundant and usually only a single series thick, although a few may be found with two series of cells in the center.

Tangential section.—The material is not sufficiently well preserved to determine the medullary rays satisfactorily.

This species is, on the whole, poorly characterized, and it is with much hesitation that I have described it as new, but as the material is too badly preserved to admit of a close comparison of its characters with those of previously described species, it seems inexpedient to refer it to any known form, or, on the other hand, to leave it entirely without a name. The discovery of better material will enable it to be either referred to a known species or establish its claim to individual specific rank.

In regard to the horizon from which this specimen comes, Professor Call writes that "it is from a large log which forms the base of a tree of large dimensions from the Orange Sands of this region. These sands I believe to be Tertiary in age. The fossil woods usually occur in the chert beds so characteristic of the region, and which are probably of Tertiary age."

Cupressinoxylon calli, n. sp.

Plate IX., Figs. 3–7.

Description.

Annual ring very distinct, 1 mm. to 3.5 mm. broad; tracheids

thick walled, provided with two or three close rows of bordered pits; medullary rays numerous, thin walled, of a single series of from 2 to 25 superimposed cells; resin tubes a chain of short cells.

Number 10, from 5½ miles northwest of Gainesville, Greene county, Arkansas. From a stump standing in position with its base imbedded in dark blue Tertiary clays. Near by were several other masses in the clays and undisturbed. This is the only locality at which the silicified woods were found in the clays; at all other places they were taken from the gravels.

Transverse section.—The annual ring is very distinct, being marked by a layer of fall wood from 6 to 15 or more cells in thickness. These cells are very thick walled, the lumen being reduced to a mere line. (Pl. IX., Fig. 4). The cells of the spring wood are very large, and begin abruptly at the ring, and gradually diminish in size until they reach and pass into the fall wood. The medullary rays as seen in this section are numerous and are separated by from two to four rows of tracheids.

Radial section.—In the spring and summer wood the tracheids are very broad and provided with two or three rows of regularly and closely placed bordered pits (Pl. IX., Fig. 5). These pits have an average outer diameter of .012 mm. and an average inner diameter of .003 mm. The medullary rays are thin walled, and in some cases, at least, provided with pits, of which there are usually three in the thickness of each tracheid. The resin tubes, as stated in the diagnosis, consist of a chain of short, rectangular cells. They have been moderately numerous.

Tangential section.—The medullary rays are arranged in a single series of superimposed cells, which varies from 2 to 25, the ordinary number being from 6 to 15. The tracheids are not provided with pits on the tangential wall.

This beautiful species, which I take pleasure in naming after the collector, shows close affinities with several described forms. It is, for example, strikingly like *Cupressinoxylon mcgeei* Knowlton* from the Potomac formation, which differs by

* Fossil Wood and Lignite of the Potomac Formation, p. 46, Pl. II, Fig. 5; Plate III., Figs. 1-5.

having the bordered pits in from 1-3 rows on the radial walls and a few scattered pits on the tangential walls. The medullary rays in *C. mcgeei* are 2-49 cells high, and are provided on the lateral walls with numerous oblong pores, while *C. calli* has the rays 2–25 cells high and the pores on the walls circular.

It is also similar to *C. glasgowi*, Knowlton* from probably Cretaceous strata of Emmett county, Iowa, which has very broad annual rings; the bordered pits in one or two series and the medullary rays of from 3 to 20 superimposed cells.

The formation from which this specimen comes is not the same as that from which *C. arkansanum* was obtained. It is from a stratum of blue clay of Eocene age according to Professor Call, and is identical in age and stratigraphic position with the clays on Bolivar Creek, 60 miles south, from which lignite was obtained.

DICOTYLEDONOUS.

Laurinoxylon branneri, n. sp.

Plate IX., Figs. 8, 9; Plate X., Figs. 1, 2; Plate XI., Fig. 4.

Description.

Transverse section.—The annual ring cannot be clearly distinguished, although there are slight evidences of its having been present. The wood cells are thick walled and ordinarily arranged in radial rows. The vessels are placed singly or arranged in radial rows of from 1-3 or rarely 4. They are usually separated by the medullary rays, although in one exceptional instance a row of three vessels was in immediate contact with another row of four. When single they are oval in shape; when more than one, each is modified by pressure. The medullary rays as seen in this section are numerous; two cells broad and usually but little curved in their course. (See Pl. XI, Fig. 4).

Radial section.—On account of the poor state of preservation it is difficult to make out the exact shape of the wood cells as seen in this section. Some of them have been rather short with square ends, but probably the larger number have had

* Proc. U. S. Nat. Mus. Vol. XI, 1888, p. 6, Pl. II, Figs. 1-5.

pointed ends. The medullary rays are in vertical plates of six to thirty or more rather long cells, and so far as can be determined were not provided with pits or markings. The large vessels are, of course, very prominent in this section. They are long, rather thick walled, and provided with numerous elliptical or nearly circular bordered pits. (See Pl. IX., Fig. 9).

Tangential section.—This section, from another portion of the same specimen, shows the wood cells clearly. Some have square and others pointed extremities (Pl. X., Fig. 1). The medullary rays are always arranged in two vertical series of from 6 to 30 or more cells. They are very numerous, as will be seen in Pl. X., Fig. 1.

The large vessels are provided with net form thickenings over the entire surface. (Pl. X., Fig. 1, and Pl. IX., Fig. 8). It seems hardly probable that the vessels have been provided with circular bordered pits on one wall and with net form thickenings on the other, since there can be no satisfactory explanation of transition from one to the other in the same vessel, but the fact remains that in all the instances in which it has been possible to make out the nature of the thickening on the walls, the circular pits are always confined to the radial walls and the net form thickenings to the tangential walls.

No. 1, from near the base of the Orange Sands, Bolivar Creek, Poinsett county; number 4, from the Orange Sands gravels, Big and Little Crow Creeks, St. Francis county, 5 N., 3 E., section 36.

This species, which has been named in honor of Dr. J. C. Branner, Director of the Geological Survey of Arkansas, is the first dicotyledonous species that has been distinguished by a study of internal structure in the United States. It very much resembles *Laurus biseriata*, Caspary* that has recently been described from Russia, but has not been nearly as well preserved and therefore does not admit of as close study and description.

Number 1 is of Eocene Tertiary age, and number 4, according to Professor Call, is probably late Tertiary.

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* Einige foss. Hoelzer Preussens, Abhandl. z. geol. Specialkarte v. Preuss. u. Thuering Staaten, Vol. IX., Pt. 2, 1889, pp. 54-60 ; Pl. X., Figs 10-17 ; Pl. XI., Figs 1-5.

Laurinoxylon lesquereuxiana, n. sp.

Plate X., Figs. 3, 4; XI., Figs. 3, 4.

Description.

Transverse section.—The annual ring is very indistinct yet clearly observable. It consists of a layer of two or three more compressed cells in which the lumen is almost entirely closed. The wood cells are much larger than in *L. branneri* and much thicker walled, and they are less clearly arranged in radial rows. They are more nearly square or by mutual pressure six-sided. The medullary rays are very numerous, three or four cells broad and run with but slight undulations amongst the wood cells. The vessels are also large and usually in twos, although it is not rare to find them single or in threes. In exceptional cases there may be four in one row and three smaller ones in another contiguous row, when the entire space between two medullary rays is filled by them. It is somewhat difficult to determine but apparently the rays have consisted of rather short cells.

Radial section.—Again on account of the poor state of preservation of the specimen it is impossible to determine with confidence the shape of the wood cells as seen in this section. That some of them have had the ends square is certain, and also some of them have been sharp jointed, but the relative proportion or distribution of the various modifications cannot be satisfactorily made out. The vessels have been numerous and large, but if there have been markings on the walls it is impossible to make them out. The vessels were filled with amorphous quartz before solidification and now appear filled with rounded drops of greater or less size (Pl. X., Fig. 3). The medullary rays as observed in this section are large, moderately short celled and filled with a black substance (Pl. X., Fig. 3). Above and below many of the medullary rays is a single or rarely double layer of large rectangular cells, likewise filled with an intensely black substance (Pl. X., Fig. 3).

Tangential section.—The medullary rays are numerous, of three or not rarely four series of superimposed cells which

are large and very thick walled. The rays are from twenty to thirty or more cells high, and very regular.

This species is, on the whole, very distinct, although it shows points of resemblance with described forms. Thus *L. diluviale*, Ung. sp.* has the peculiar large rectangular cells on each side of the medullary rays but differs in most of the other characters. *Laurus triseriata*, Caspary,† recently described from Prussia resembles it yet differs in important points.

The specimens are the collector's numbers 2 and 3, from the bed of Rice Branch on Spanish Grant 239, near Wittsburg, Cross county. The material is derived from the adjacent Orange Sands, and of Tertiary age.

I have named this species in memory of Prof. Leo Lesquereux, whose numerous and valuable works will ever remain a monument to American paleontology. It is moreover specially fitting that his name should be associated with a species from Arkansas, for, as is well known, he was at one time much interested in the fossil plants from this state and prepared a report upon the collections made under the direction of the Owen Survey.

Laurinoxylon?

Number 9 from the base of Red Bluff, south side of Arkansas River, Jefferson county, and derived from the Orange Sands capping the higher lands a mile or so back from the river.

The material is not sufficiently well preserved to admit of identification and is only provisionally referred to the genus *Laurinoxylon*. It can hardly be either of the species described above, yet it resembles them in a general way. Further material from the same locality may clear up the doubt regarding this species as well as furnish material for a more complete diagnosis of the other species.

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* Felix, Untersuch. u. foss. Hoelz. Deutch. Geol. Gesell. Zeit. XXXV., 1883, p. 59, Pl. II., Fig. 2, 3; Pl. III., Fig 1.

† Einige foss. Hoelzer. Preussens. Abhandl. z. geol. Specialkarte v. Preuss. u. Thuering Staaten. Vol. IX., Pt. 2, 1889, pp. 60-67; Pl. XI., Figs. 6-12; Pl. XII., Figs 1-5.

In regard to conclusions that are to be drawn from this study concerning the probable age of the strata containing the specimens, it can only be said that the study of the internal structure of the fossil plants is as yet so young and undeveloped in this country, that there are very few known species available as stratigraphic marks. All of the species in this collection I have unfortunately been obliged to describe as new, since they do not appear to have been before described, and they can therefore have little value in determining close questions of age. But it is hoped that the strata with which they are now identified may be more readily recognized in the future by a study of the lignite and silicified material.

Professor Call writes that he has accumulated a considerable amount of evidence of a chemical nature to show that the origin of the fossil woods of the chert beds (Tertiary) is to be sought in the underlying Tertiary clays of the region. That is that some of these woods at least may be the silicified lignite of the region. This evidence is fully presented by Professor Call in his report on Crowley's Ridge, and I can only say that so far as the study of this wood and lignite is concerned this theory is not improbable. Almost all of the silicified material, in fact all but one piece, is dicotyledonous, and while a large proportion of the Eocene lignite is coniferous, as has been stated above, also a considerable amount that is undoubtedly dicotyledonous, and, so far as could be determined, it is similar to the silicified material.

Plate IX.

Figs. 1, 2. *Cupressinoxylon arkansanum*, n. sp., p. 253.
- 1. Section radial.
- 2. Section transverse.

Figs. 3, 7. *Cupressinoxylon calli*, n. sp., p. 254.
- 3. Section transverse, showing medullary rays.
- 4. Section transverse, passing through annual ring.
- 5. Section radial, showing bordered pits.
- 6. Section radial, showing pits on medullary rays.
- 7. Section radial, showing chain of resin cells.

Figs. 8, 9. *Laurinoxylon branneri*, n. sp., p. 256.
- 8. Section tangential, showing thickening on walls of ducts. Highly magnified portion of section seen in Pl. X., Fig. 1.
- 9. Section radial, showing pitted markings on radial walls of ducts. Highly magnified portion of duct seen in section on Pl. XI., Fig. 4

PLATE IX.

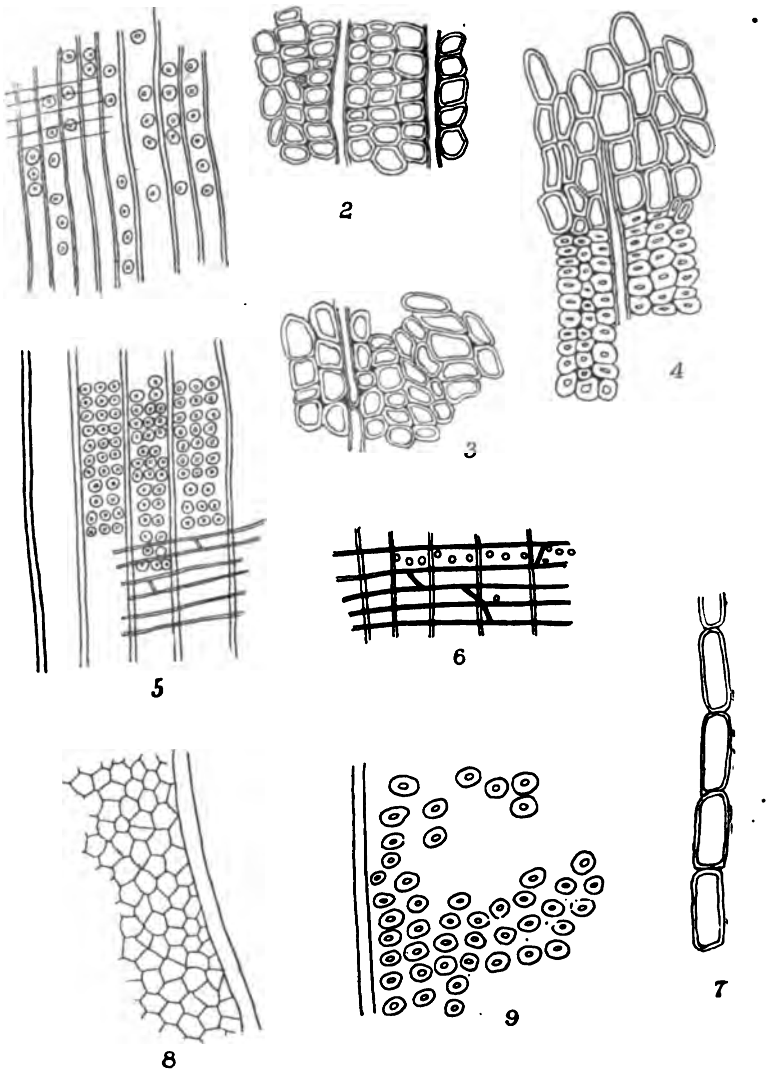


Plate X.

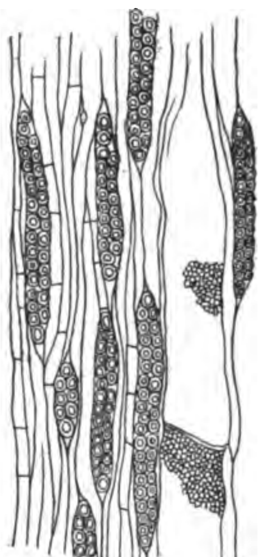
Figs. 1, 2. *Laurinoxylon branneri*, n. sp., p. 256.

1. Section tangential, showing large duct with net formed thickening and rays in two series.
2. Section transverse, showing arrangement of ducts and rays.

Figs. 3, 4. *Laurinoxylon lesquereuxiana*, n. sp., p. 258.

3. Section radial, showing the cells of the rays and and the numerous ducts filled with a dark colored substance.
4. Section tangential, showing a single large duct and the rays arranged in three or four series.

PLATE X.



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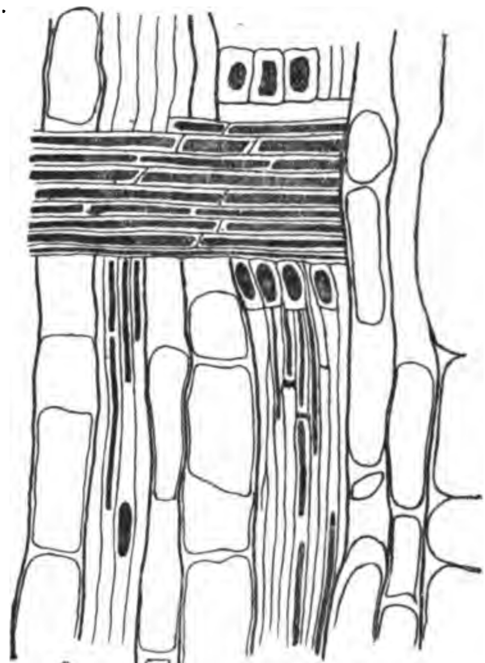

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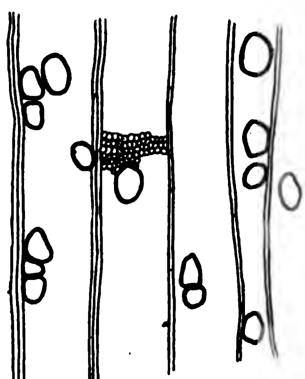

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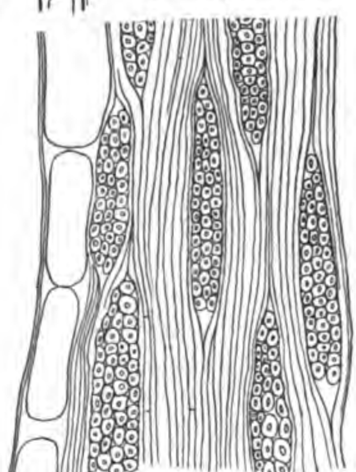

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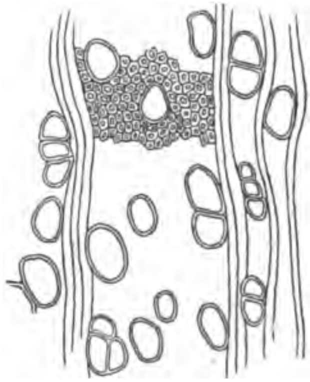
Plate XI.

Fig. 3. *Laurinoxylon lesquerexiana*, n. sp., p. 258.
Section transverse, showing ducts and the thick wood cells.

Fig. 4. *Laurinoxylon branneri*, n. sp., p. 256.
Section radial, showing ducts and large medullary rays. Too poorly preserved to show the wood cells correctly.

PLATE XI.



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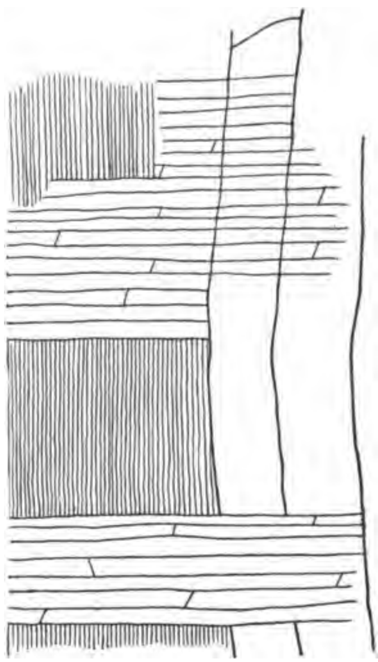

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